URANIUM IN CANADA

1991

ASSESSMENT of SUPPLY and REQUIREMENTS

THE ENERGY OF OUR RESOURCES

THE POWER OF OUR IDEAS

93-00387/

URANIUM IN CANADA

1991 ASSESSMENT OF SUPPLY AND REQUIREMENTS

The Uranium Resource Appraisal Group (URAG) congratulates the Geological Survey of Canada on the occasion of its 150th anniversary and wishes it continued success in the future. URAG is proud to be associated with this world renowned organization, which has played a key role in the Group's activities since its inception in 1974.

REPORT EP 91-3
September 1991

Preface

Assessing Canada's uranium resources as of January 1, 1991, this report reviews the developments in the Canadian uranium industry during 1989 and 1990, and through the second quarter of 1991. To clearly reflect this coverage, the 1991 date has been used in the report title. The 1991 report, therefore, represents the latest formal release in this biennial series, following the 1989 report.

Acknowledgments

The Uranium Resource Appraisal Group is grateful to the uranium mining industry of Canada for its assistance and co-operation in contributing data for this report, and to the representatives of the Ontario Ministry of Northern Development and Mines, and of Saskatchewan Energy and Mines, for assistance in assessing uranium resources within their respective domains.

The interpretation of uranium resource data presented herein was made possible by the efforts of Messrs. A. Fustos, D. Walsh, A. Boyer, N. Billette and R. Boyle of EMR's Canada Centre for Mineral and Energy Technology (CANMET), and Messrs. V. Ruzicka, S.S. Gandhi, R.T. Bell and N. Prasad of EMR's Geological Survey of Canada (GSC). The report was compiled by R.T. Whillans in the Uranium Division of EMR's Electricity Branch (Energy Sector).

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CANADIAN URANIUM INDUSTRY FACT SHEET

		1990	1989	1988	1987
Known Uranium Resources Recoverable from Mineable Ore (000 tU as of January 1)		583	544	559	567
Annual [Primary] Production (tU)					
Ontario	- Elliot Lake (Rio Algom)	1 663	2 210	2 349	2 405
	- Elliot Lake (Denison)	1 319	1 697	1 876	1 809
Saskatchewan	- Key Lake (Cameco/UEM)	4 976	4 893	4 629	5 199
	- Rabbit Lake (Cameco/UEM)	0	1 796	2 679	2 193
	- Cluff Lake (Amok/Cameco)	771	727	860	829
Total [Primary] Production (tU)		**8 729***	**11 323***	**12 393***	**12 435**
Share of Western World Output (%)		30	33	34	34
Domestic Reactor Requirements (tU)		1 900	1 800	1 700	1 500
Ontario Producer Shipments (tU)		4 597	4 099	3 872	4 901
Value of Shipments (CAN$ millions)		627	501	446	581
Saskatchewan Producer Shipments (tU)		5 123	6 896	8 194	8 711
Value of Shipments (CAN$ millions)		261	412	573	601
Total Producer Shipments[§] (tU)		**9 720**	**10 995**	**12 066**	**13 612**
Value of Shipments (CAN$ millions)		**888**	**913**	**1 019**	**1 182**
Average Price for Deliveries under Export Contracts	- (CAN$/kgU)	71	74	79	79
	- (US$/lb U_3O_8)	24	24	25	23
Spot Sales Proportion of Deliveries under Export Contracts (%)		< 1	< 1	13	35
Average Annual "NUEXCO" Spot Market Price (US$/lb U_3O_8)		9.76	10.00	14.55	16.78
Canadian Uranium Under Export Contracts Reviewed/Accepted during the Year (tU)		7 900	10 298	14 049	6 427
Actual Exports of Uranium of Canadian Origin (tU)		8 648	9 398	10 434	12 789
Uranium Exploration Expenditures in Canada (CAN$ millions)		45	58	59	37
Employment as of Dec. 31st (Mine + Mill + General)		2 495	4 280	4 730	4 825

* *Primary output. In 1990, an additional 50 tU was recovered by Elliot Lake producers from refinery/conversion facility by-products, compared to about 31 tU in 1989 and 73 tU in 1988.*

§ *for Domestic and Export customers*

EXECUTIVE SUMMARY

Canada is the largest supplier of uranium in the world, with annual output accounting for almost a third of total Western world production. Uranium ranks sixth in value of production among Canada's top ten metals. In 1989, primary production in Canada exceeded 11 320 metric tons[§] (t) of uranium (U), but output declined in 1990 due to general market weakness. Canada's uranium producers reported 1990 production of concentrates containing about 8 730 tU, and shipped some 9 720 tU, valued at CAN$888 million.

Canada has a large portion of the world's known (discovered) lower-cost uranium resources, standing fourth behind Australia, Niger and South Africa. Because its geology is favourable for the discovery of additional resources, Canada continues to host a significant share of international uranium exploration activity. The Athabasca Basin in northern Saskatchewan is the principal target for the discovery of very high-grade, low-cost, uranium deposits.

The domestic market requires about 20 per cent of current Canadian output. The remaining uranium produced in Canada is exported solely for the peaceful purpose of generating electricity abroad. Canada has three major export markets: the United States, East Asia and Western Europe, and each takes a significant share of Canada's exports. In recent years, annual uranium exports have varied from 8 000 to 12 000 tU.

Notwithstanding its strong position, Canada's uranium industry faced an uncertain market in 1990, plagued by oversupply and low and volatile prices. Brokers and traders became increasingly active during the year, moving excess supplies into the market and thus contributing to increased spot-market price volatility. The NUEXCO Exchange Value* [spot-price indicator] swung between a July high of US$11.70/lb U_3O_8 and the all-time low in October of US$8.35/lb. In Canada by comparison, the average price of all export deliveries in 1990 was CAN$71/kgU (US$24/lb U_3O_8), slightly below the 1989 average. However, Canada's uranium producers signed new export contracts in 1990 to deliver about 7 900 tU. As well, development is proceeding at several projects in anticipation of market opportunities later in the 1990s. [1]

As the uranium market weakened, and prospects for a near-term turnaround became increasingly doubtful, some Canadian uranium producers trimmed output levels and others purchased uranium on the spot market. At Elliot Lake, Ontario, Rio Algom Limited closed its Quirke and Panel mines in August 1990, and Denison Mines Limited reduced its workforce in line with production cuts. In early 1991, Denison announced that its operation would close in 1992 upon completion of deliveries under its contract with Ontario Hydro, and Rio Algom announced that its Ontario Hydro contract would be continued only until 1996.

In April 1991, six proposals for new uranium mining facilities in Saskatchewan were referred to the federal Minister of the Environment for public review by an independent Panel, pursuant to the Government of Canada's Environmental Assessment and Review Process (EARP) Guidelines Order. Five proposals will be reviewed by a joint federal-provincial Panel, namely: Cluff Mining's South and West Dominique-Janine expansion, Denison's Midwest Joint Venture South McMahon Lake project, Minatco Limited's McClean Lake project, Cigar Lake Mining Corporation's Cigar Lake project, and Cameco Corporation's McArthur River project. The sixth proposal, Cameco's Eagle Point/Collins Bay A & D expansion, will be reviewed by a federal-only Panel, as conditional approval has already been granted for the project by Saskatchewan authorities. [2] The start-up date of any of these projects depends on developments in the international uranium market, as well as on the receipt of the necessary regulatory and environmental approvals.

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§ *One metric ton (tonne) of elemental uranium (U), written as tU, is equivalent in terms of uranium content to 1.2999 short tons of uranium oxide (U_3O_8).*

* *The price at which transactions for significant quantities of natural concentrates could be concluded as of the last day of the month according to the Nuclear Exchange Corporation (NUEXCO), a Colorado-based uranium brokerage firm.*

Canadian uranium exploration and development efforts in 1989 and 1990 led to the discovery of significant new uranium resources. [3] These additions more than compensated for the loss in resources from primary production, of over 20 000 tU in 1989 and 1990, and from the adjustments at Elliot Lake, Ontario, including consideration for the closure of Rio Algom's Quirke and Panel mines in mid-1990. The estimate of overall Canadian uranium resources as of January 1, 1991 was up by almost 10 per cent from January 1, 1989, as shown in the table below.

Principal resource categories	Tonnes U* recoverable from mineable ore	
	1/1/91	1/1/89
Measured	49 000	65 000
Indicate	222 000	224 000
Inferred	323 000	255 000
Total	594 000	544 000

**One metric ton (tonne) of elemental uranium (U), written as tU, is equivalent in terms of uranium content to 1.2999 short tons of uranium oxide (U_3O_8).*

Despite the overall increase in uranium resources during 1989 and 1990, the erosion of resources that will be reflected in upcoming assessments due to the planned mine closures at Elliot Lake, Ontario, could have a negative impact on Canada's future uranium resource adequacy. It is clear that the continued availability of sufficient resources to meet Canada's domestic and export requirements could depend very much on the outcome and timing of the environmental review of new uranium mining projects in Saskatchewan.

In 1988 and 1989, overall uranium exploration expenditures in Canada approached CAN$60 million, but declined to $45 million in 1990 as the market weakened. The maintenance of such high levels of exploration activity is due largely to the test mining programs underway at the Cigar Lake project in Saskatchewan where advanced underground exploration (geotechnical testing) included shaft sinking and lateral development. Combined exploration and surface development drilling in 1989 and 1990 reached 158 000 m and 66 000 m, respectively, approximately 90 per cent of which was in Saskatchewan.

Over the past few years it has become clear that world reactor requirements cannot be met by output from current production centres relying on low-cost resources, and most analysts have concluded that new production facilities will be required in the mid-1990s. However, the oversupply situation has been exacerbated recently by the availability of low-priced uranium from the U.S.S.R., from the German uranium stockpile, and from certain Eastern European countries and China. The emergence of these non-traditional suppliers and the increased availability of surplus inventory suggests that the need for new sources of uranium production could be delayed beyond the mid-1990s. The timing of many of the potential new production projects could well depend on the supply-diversification strategies of the world's nuclear utilities.

A recent study on the impact of taxation on uranium mining in Canada and Australia, prepared jointly by the Centre for Resource Studies (CRS) at Queen's University, Kingston, Ontario, and the Uranium Division of the Department of Energy, Mines and Resources (EMR), demonstrates quite clearly that only the very best uranium mining projects will have a chance of being developed under current market conditions. Moreover, growing public interest in protecting the environment will mean that new uranium mining projects must undergo intensive scrutiny. This may increase the lead times needed for new developments, perhaps contributing to tightened supply and a strengthening of uranium prices later in the decade. Clearly, quite exceptional targets will be required to provide the economic justification for uranium exploration. [4]

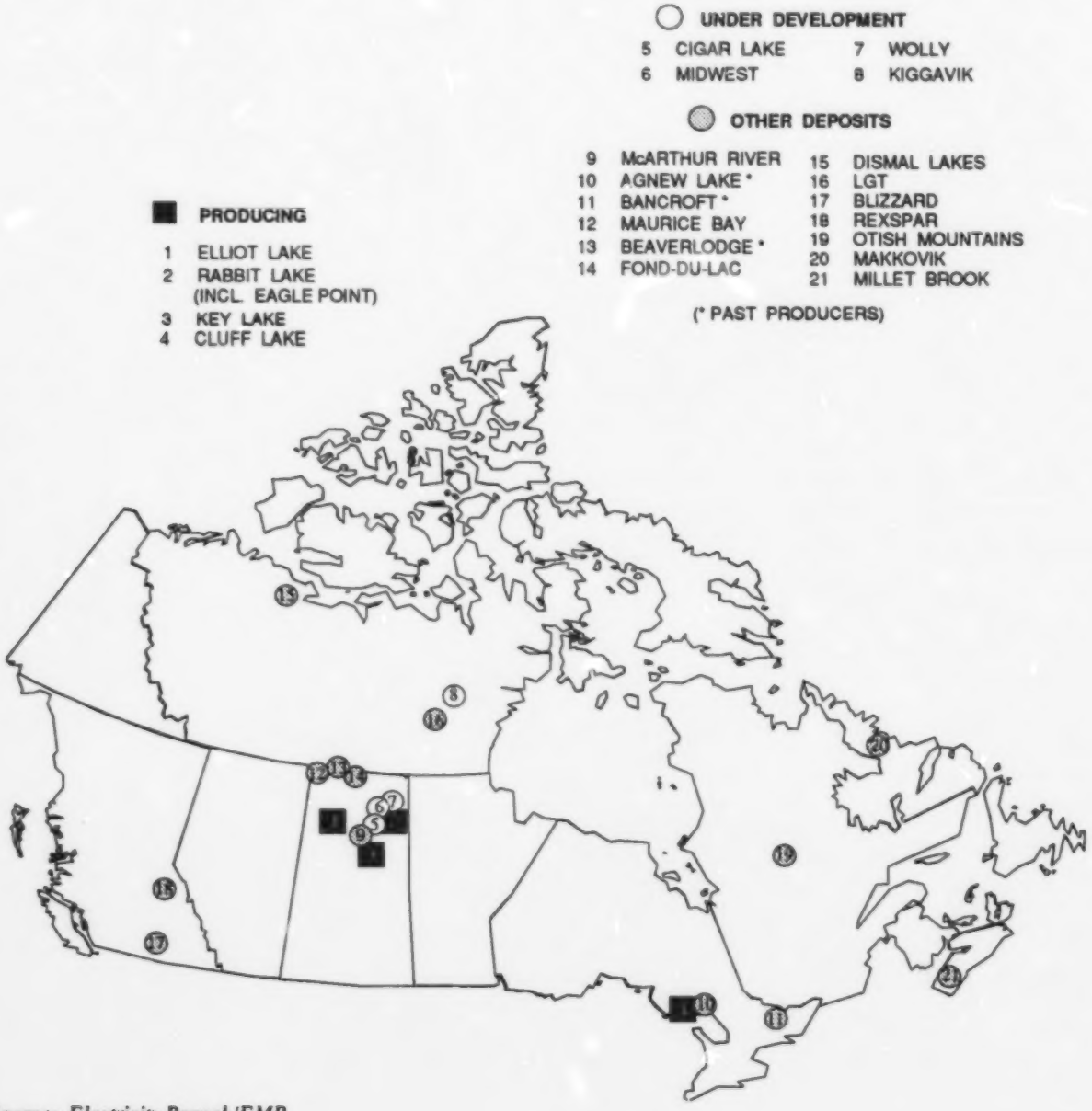
In late 1990, the International Atomic Energy Agency (IAEA) reported that global consumption of electricity was projected to grow at an annual rate in excess of 3 per cent, with nuclear-electric generation increasing at slightly less than 3 per cent per annum. Since 1986,

the year of the Chernobyl accident, more than 80 new nuclear plants have been brought on line worldwide; an additional 83 nuclear reactors were under construction as of January 1, 1991. In just 30 years, nuclear power's share of rapidly increasing total world electricity generation has risen from less than 1 per cent to about 17 per cent.

Beyond 2000, the future of nuclear power may be affected by decisions taken in the next few years with regard to the environment. The growing awareness that nuclear power plants contribute little to global warming, and rising concern about the emission of CO_2 and other "greenhouse" gases may result in increased orders for nuclear power plants. In France, for example, emissions of CO_2 have fallen steadily over the past decade as nuclear's share of total electricity generation has risen to its current value of 75 per cent. In Sweden there has been a clear change in attitude, whereby the major political parties have reconsidered the 1988 decision to close two of the country's twelve nuclear power reactors by 1996.

In adjusting to the highly volatile market conditions of recent years, Canada's uranium producers are better prepared for the challenge of the 1990s. Looking to the future, Canada has the uranium resources, the infrastructure, the political will and determination, to remain a reliable and competitive supplier of uranium to its trading partners for many years to come.

Figure 1. Uranium Deposits in Canada



Source: Electricity Branch/EMR

Part I. SHORT-TERM PERSPECTIVE

1. SUPPLY

A) Supply Sources

Measured, Indicated and Inferred Resources

Canadian uranium supply over the next 10 to 15 years will be drawn from known resources, estimates of which are divided into three major categories, measured, indicated and inferred, that reflect different levels of confidence in the reported quantities. Most of these resources are associated with those deposits identified in Figure 1. The current estimates of resources in these three categories, prepared by EMR's Uranium Resource Appraisal Group (URAG), are presented in Table 1.

A comparison of current estimates of Canadian uranium resources with those reported previously [5] (see Table 1), indicates that resource additions from

Table 1. Estimates of Canada's Uranium Resources Recoverable from Mineable Ore[1], 1/1/91 and 1/1/89

(Thousands of tonnes of uranium)

Price ranges within which mineable ore is assessed[2]	Measured		Indicated		Inferred	
	1/1/91	1/1/89	1/1/91	1/1/89	1/1/91	1/1/89
A	29	41	117	98	149	109
B	3	2	65	94	80	95
A + B	32	43	182	192	229	204
C	17	22	40	32	94	51
A + B + C	49	65	222	224	323	255

[1] *Actual or expected losses in mining recovery and ore processing have been accounted for; these factors were individually applied to resources tributary to existing or prospective production centres. In underground operations, mineable ore is generally 75 to 85 per cent of the ore-in-place; higher mining recoveries are achievable in open-pit operations. Ore-processing recoveries in Canada normally range from 90 to 97 per cent; Canada's weighted average mill recovery for existing conventional uranium operations was 96 per cent in 1990.*

[2] *The price ranges are (A) $100/kgU or less, (B) between $100 and $150/kgU and (C) between $150 and $300/kgU. The Canadian dollar figures reflect the price of a quantity of uranium concentrate containing 1 kg of elemental uranium. The prices were used in determining the cut-off grade at each deposit assessed, taking into account the mining method used and the processing losses expected. The price of $100/kgU was used by URAG to illustrate those resources that were of economic interest to Canada in 1988 and 1990.*

$1/lb U_3O_8 = $2.6/kgU

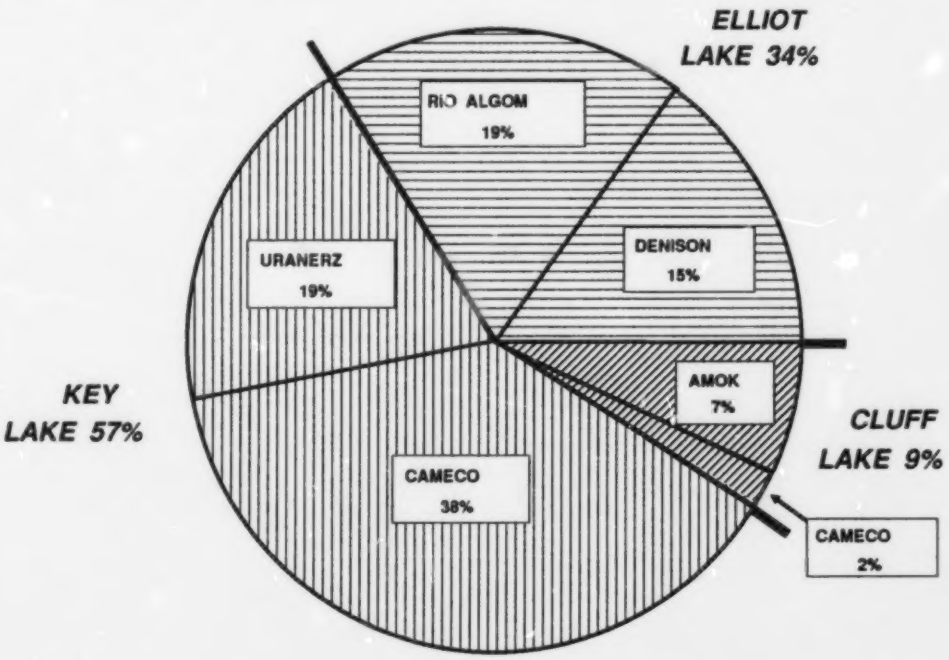
new discoveries more than replaced the depletion by production and loss of reserves over the two-year assessment period. The net overall increase in resources reflects the discovery of significant new deposits; these additional resources have more than offset the draw-down of some 20 000 tU due to 1989 and 1990 production, and the loss of resources as a result of developments at Elliot Lake, Ontario, including consideration for mine closures in the area.

Of Canada's combined measured, indicated and inferred resources presented in Table 1, almost two-thirds occur in unconformity-related-type deposits, primarily in northern Saskatchewan. These contain either monometallic (Eagle Point) or polymetallic (Key Lake and Cigar Lake) mineralization associated with the sub-Athabasca unconformity.

In the monometallic deposits, the mineral pitchblende prevails whereas in the polymetallic deposits uranium-nickel-cobalt assemblages are usually predominant. Average grades can vary from below 1 per cent U to between 2 and 5 per cent U, while in parts of certain deposits (Cigar Lake) grades can exceed 10 per cent U.

Most of Canada's other known uranium resources occur in quartz-pebble conglomerates, primarily in the Elliot Lake area of Ontario. The ore occurs in several beds and grades on average between 0.05 and 0.1 per cent U.

Figure 2. Canadian Uranium Production and Ownership, 1990



1990 Primary production = 8 730 tonnes U
Note: Cameco's Rabbit Lake Mill was closed throughout 1990.

Source: Electricity Branch/EMR

B) Uranium Availability

Existing Operations [1/2]

As of January 1991, only four uranium production centres were operating in Canada. At Elliot Lake, Ontario, both Rio Algom Limited and Denison Mines Limited had one operation in production; both operate conventional underground mines and also recover uranium using in-place leaching techniques. In Saskatchewan, Cluff Mining and Cameco Corporation* each had one conventional operation in production; a second Cameco operation was on standby. Cameco produces from open-pit mines whereas Cluff Mining produces from both open-pit and underground mines.

In July 1990, Cameco sold Uranerz Exploration and Mining Limited (UEM) a one-third interest in its Rabbit Lake operation and associated properties. Cameco and UEM now have identical equity splits (2/3 and 1/3, respectively) in both the Key Lake and Rabbit Lake operations, although Cameco operates both. UEM had acquired a one-third interest in the north part of the Eagle Point deposit in 1988 from Noranda Exploration Company, Limited. (See Fig. 2.)

Under the 1988 agreement, whereby Cameco was formed by the merger of Canada's two government-owned uranium companies, government shareholdings in the company were to have been reduced by 30 per cent within two years, 60 per cent within four years, and 100 per cent within seven years. In 1990, Cameco announced that its first public share offering would be delayed a second time due to the depressed uranium market. However, Cameco filed a preliminary prospectus in May 1991 and subsequently signed an underwriting agreement for its initial share offering. More than 10 million shares were offered in July at a price of $12.50 each and within days the offering was fully subscribed, the gross proceeds reaching $130 million. Cameco is now held 20 per cent by the public, 49.2 per cent by the Government of Saskatchewan, and 30.8 per cent by the Government of Canada.

As shown in Table 2, about 2 500 employees worked at Canada's five existing uranium-producing operations as of January 1991.

Table 2. Uranium-Producing Workforce in Canada

Company (operation)	*Employees (mine/mill/general)*
Cluff Mining	145
Denison Mines Limited	1 300
Cameco - (*Rabbit Lake*)	230
- (*Key Lake*)	370
Rio Algom Limited (*Stanleigh*)	450
Total (January 1, 1991)	2 495

Elliot Lake, Ontario, Operations

In 1989, Rio Algom continued with redevelopment work at the past-producing [Milliken/Lacnor/Nordic] properties adjoining its Stanleigh operation, and Denison started mining at its adjoining Canuc property ahead of schedule. However, during 1990 the uranium market deteriorated to the point that Rio Algom was forced to close two of its three mines (Quirke and Panel) in August, and Denison had to reduce its workforce by about 450 in line with expected cuts in uranium production.

In April 1991, Denison announced that Ontario Hydro had given Notice of Termination of its uranium supply contract, effective January 1, 1993, and that Denison would permanently close its operation upon completion of contract deliveries, affecting some 1 000 workers. Subsequently, Denison reached an agreement with Ontario Hydro, whereby 1991 and 1992 deliveries will be accelerated, permitting current production and workforce levels to be maintained until closure in the second quarter of 1992.

* *On November 1, 1990, the official name of* Cameco - A Canadian Mining & Energy Corporation *was shortened to* Cameco Corporation.

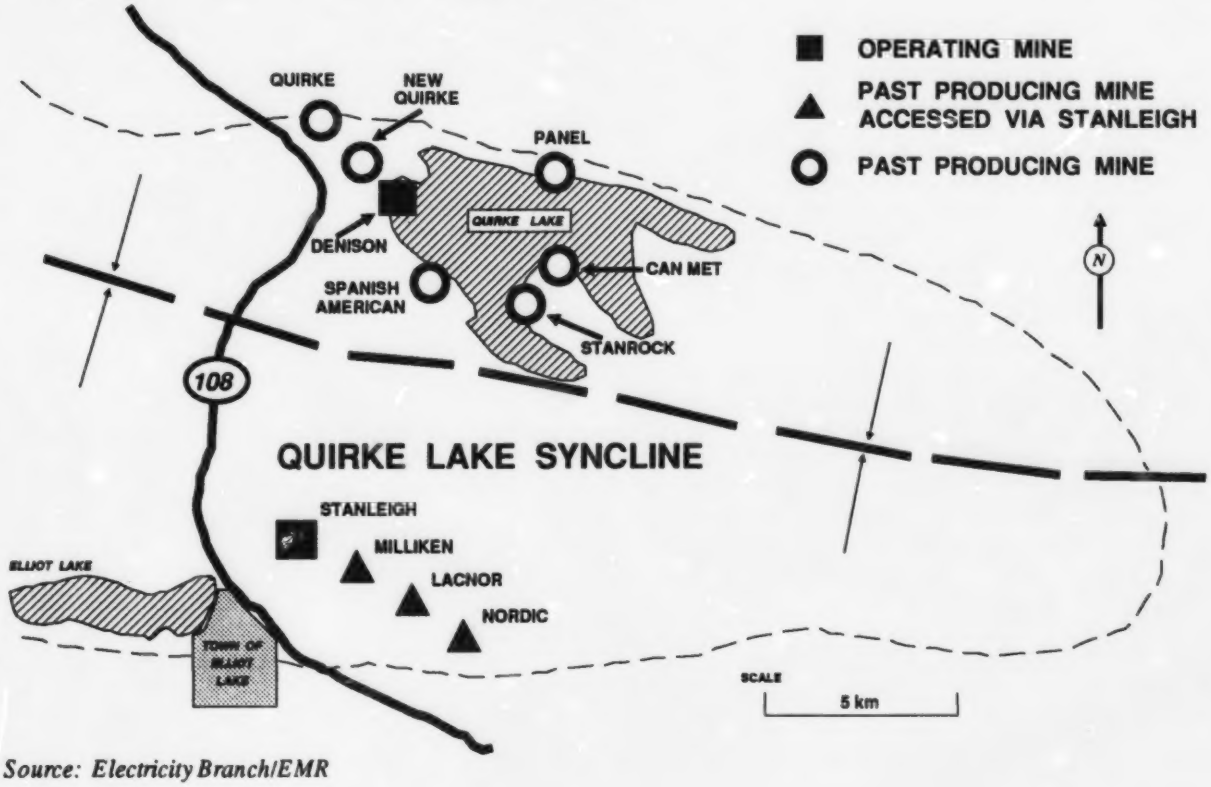
In June 1991, Ontario Hydro announced that it had agreed to continue Rio Algom's current (Stanleigh mine) contract beyond the end of 1993, but only until 1996 as opposed to the original 2020 date. Deliveries will be increased between 1992 and 1995, but at a lower average price, requiring the addition of up to 75 employees by early 1992. Stanleigh employed almost 500 at year end 1990, some of whom were involved in asset disposal and environmental decommissioning activities related to the closure of Rio Algom's Quirke and Panel mines. [6]

The 1991 closure announcements did not come as a complete surprise in view of the 1990 shutdowns by Rio Algom of its Quirke and Panel operations. By mid-1991, over 2 000 jobs, representing more than 50 per cent of the uranium-producing workforce, had been affected by closures and cutbacks. The population of Elliot Lake has declined from over 16 000 two years ago to around 12 500 by early 1991.

The Government of Ontario, in close cooperation with relevant federal government departments and agencies, has undertaken several initiatives in an effort to lessen the impact of this employment loss. In December 1990, it announced that the Elliot Lake area would receive $15 million to help diversify and revitalize its economy.

In June 1991, the Ontario government announced a multi-million dollar package to help the Elliot Lake area make the transition from a dependence on uranium mining to a more diversified economy.

Figure 3. Elliot Lake, Ontario, Producing District



Source: Electricity Branch/EMR

Ontario Hydro will provide $65 million to help the affected communities for both short-term adjustments and long-term diversification, and $25 million for a number of energy initiatives, such as local energy efficiency programs and developing co-generation potential. In addition, the utility estimates that its commitment to purchase uranium until 1996 represents a $160 million premium above current uranium market prices.

In all likelihood the closure of the last Elliot Lake operation in 1996 will bring to an end an important chapter in the history of Canadian uranium production dating back to the mid-1950s. It appears unlikely that the remaining uranium resources will be economically recoverable by conventional methods in the near future.

Figure 3 shows the status of known deposits in the Elliot Lake, Ontario uranium-producing district.

The key data for Canada's uranium production centres are shown in Table 3.

Table 3. Operational Characteristics of Existing Canadian Uranium Production Centres in 1990

Company and plant location	Deposit type[a] and mining method[b]	Ore-processing plant*			
		Method[c] and recovery (%)	Rated mill capacity/Ore throughput (tonnes/day)	Annual ore milled (tonnes)	Average ore grade processed (% U)
Cluff Mining-Phase II Cluff Lake, Sask.	Ucon/OP/UG	AL/SX/96	+ 900/850	127 000	0.64
Denison Mines Limited Elliot Lake, Ont.	Cong/UG/IPL	AL/IX/94	7 700/6 670	1 942 000	0.07
Cameco Corporation Rabbit Lake, Sask.	Ucon/OP	AL/SX/N.A.	2 000/N.A.	N.A.	N.A.
Cameco Corporation Key Lake, Sask.	Ucon/OP	AL^2/SX/99	+ 800/+ 820	264 000	2.0
Rio Algom Limited Elliot Lake, Ont.					
- Quirke mill	Cong/UG/IPL	AL/IX/93	5 000/4 580	1 176 400	0.07
- Panel mill	Cong/UG/IPL	AL/IX/92	3 000/2 800	679 700	0.07
- Stanleigh mill	Cong/UG/IPL	AL/IX/95	+ 4 500/2 750	605 100	0.08

* *Figures rounded*

[a] *Deposit types: conglomeratic (Cong), unconformity related (Ucon).*

[b] *Mining methods: underground (UG), open-pit (OP), in-place leaching (IPL).*

[c] *Ore-processing methods: acid leaching (AL), two-stage acid leaching (AL^2), ion exchange (IX), solvent extraction (SX).*

N.A. Not Applicable.

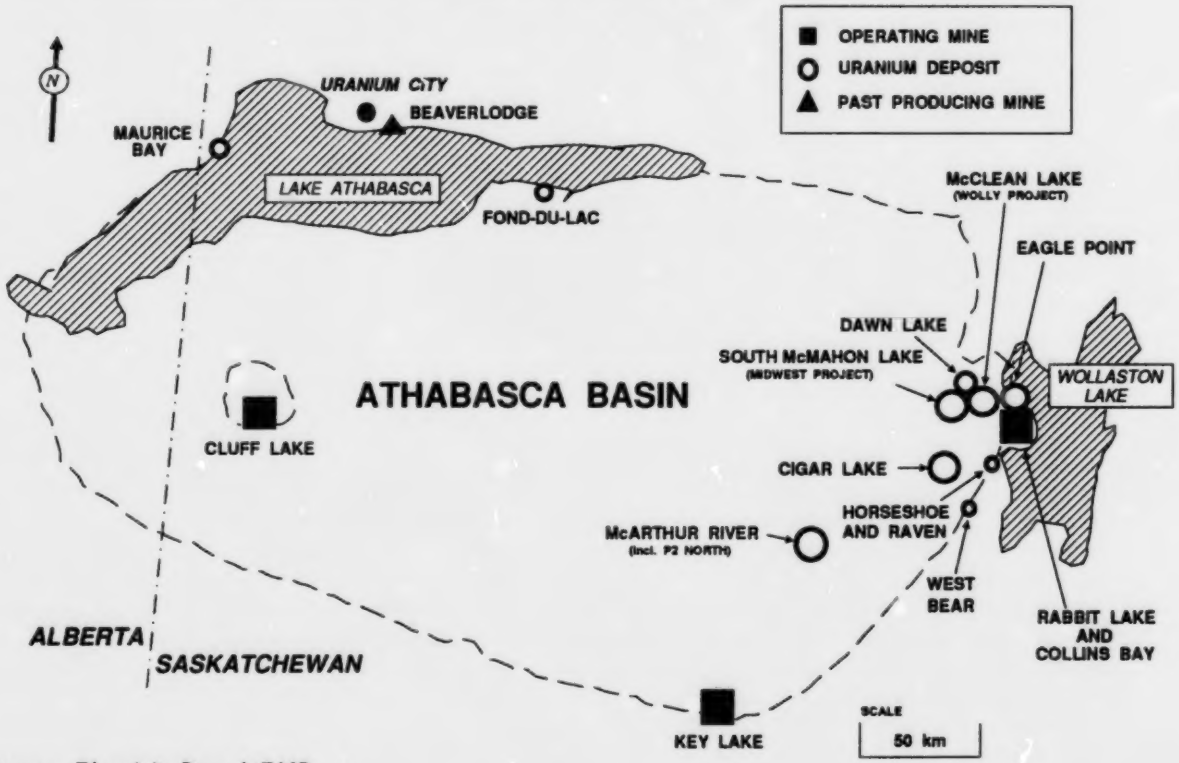
Sources: Corporate annual reports and the Atomic Energy Control Board (AECB).

Athabasca Basin, Saskatchewan, Operations

In Saskatchewan, milling was suspended at Cameco's Rabbit Lake operation in July 1989, due to poor market conditions, and mining operations ceased as well for six weeks in mid-1990. The Collins Bay "B" orebody was mined out during 1990 and the ore stockpiled at the Rabbit Lake mill. In October 1990, the Atomic Energy Control Board (AECB) renewed the operating licence for Rabbit Lake, and approved an increase in output levels to a maximum of 5 400 tU annually. Milling resumed in August 1991, and by 1996, annual output capacity is expected to have reached 4 600 tU. Having received regulatory approval to proceed with test mining of the Eagle Point, Collins Bay A and D deposits, Cameco had site preparations at Eagle Point well underway in late 1990, with work focussing on construction of a decline.

At Cameco's Key Lake operation, the larger Deilmann pit was prepared for mining in 1989, the Gaertner pit having been mined out. In mid-1990, the operation closed for six weeks due to continued market weakness. However, nominal mill capacity in 1990 was exceeded to compensate for the summer closure of both the Rabbit Lake and Key Lake operations. Mining at Key Lake has been accelerated so that the Deilmann pit can be mined out by 1995 for use as a tailings impoundment facility.

Figure 4. Athabasca Basin, Saskatchewan, Uranium Deposits



Source: Electricity Branch/EMR

In August 1989, Cluff Mining ceased ore processing due to the depressed market, but resumed milling in January 1990 on an alternate-week basis. With mining completed at the Claude pit during 1989, output from the new Dominique-Janine North pit supplemented ore from the Dominique-Peter underground mine, which resumed production in April 1990. Expecting ore depletion at Dominique-Janine North in 1991, Cluff Mining plans to extend the pit southward and at year-end 1990 submitted an Environmental Impact Statement (EIS) to the AECB for approval.

Figure 4 shows the major uranium deposits and existing and potential production centres of the Athabasca Basin in northern Saskatchewan.

Projected Production Capabilities

With the closure of Rio Algom's Quirke and Panel mines in 1990, production capability of Canada's existing operations was reduced by more than 15 per cent. Although the expansion of installed capacity at Cameco's Rabbit Lake operation has more than offset the loss at Elliot Lake, it is uncertain when the enlarged facility will be fully utilized. Canadian output in 1991 may remain below capability, as producers continue to avoid the spot market and gear output to their existing contract commitments. At some operations, significantly higher uranium prices would be required to bring production up to full capacity.

To illustrate Canadian uranium availability in the short term, Table 4 and Figure 5 provide a projection of Canadian production capability to the year 2005. The projection of firm production capability is based only on existing production centres, as listed in Table 2. It assumes a level of production that could be realistically achieved, under current circumstances, supported by known resources in the so-called low-cost category; these known resources are recoverable at a price of $100/kgU or less, i.e., supported by "A" priced resources only.

It should be noted that compared with previous assessments, Canada's production capability shown below reflects a reduction after 1992, i.e., the closure of the Denison operation, and again in 1996, i.e., the closure of Rio Algom's Stanleigh operation.

Table 4. Canadian Uranium Production Capability from Existing Production Centres

Projection based on "A" priced resources only

	(annual tonnes U output)				
1991	8 940	*1996*	9 330	*2001*	5 040
1992	9 710	*1997*	7 340	*2002*	5 040
1993	9 630	*1998*	6 240	*2003*	5 040
1994	9 530	*1999*	5 040	*2004*	5 040
1995	9 430	*2000*	5 040	*2005*	5 040

The lives of some of Canada's existing uranium production centres could be extended through the addition of resources resulting from continued exploration and development work. No firm commitments have been made for the start-up of any production centres beyond those currently in operation. Developments in the international uranium market and uncertainty regarding the costs associated with certain of the planned projects noted below (see Additional Production Possibilities), make it very difficult to project Canadian production capability levels in the future with any precision.

Additional Production Possibilities

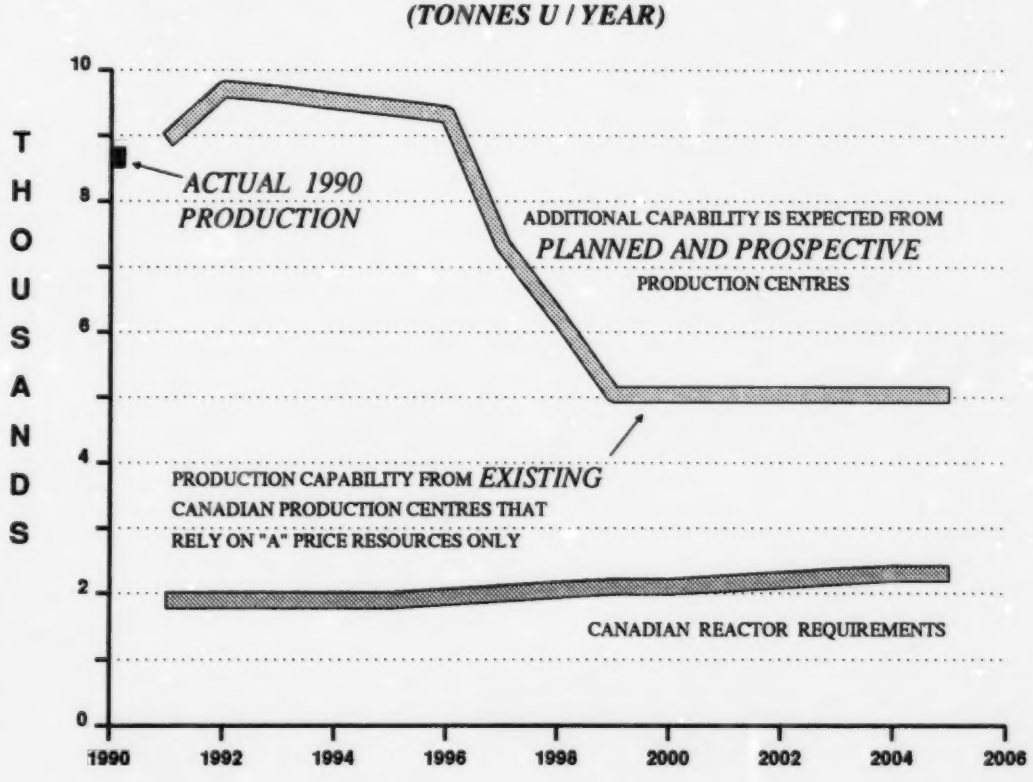
In addition to the existing operations described above, several other projects could become uranium producers before the end of the 1990s, should market conditions warrant. These projects are noted in Table 5. The start-up date of any of these projects is contingent on the receipt of the necessary regulatory and environmental approvals and on developments in the international uranium market. (See Executive Summary.)

At the Cigar Lake project in Saskatchewan, the 500m deep shaft, which was started in September 1988, was completed in May 1990. Lateral development work is

continuing in preparation for a planned test mining program. On the thicker ore sections, vertical mining is foreseen, either by blind-hole boring (down) or box-hole boring (up), while undercut and fill methods are possible on the thinner ore sections. The Cigar Lake deposit, the world's largest and richest uranium orebody, has known geologic resources that total 150 000 tU in ore grading 10 per cent U. Test mining and bulk sampling could be completed in 1991 to permit preparation of an EIS and mining feasibility report during 1992. Owners of Cigar Lake Mining Corporation, the project operator, include Cameco (48.75%), Cogema Canada Limited (36.375%), Idemitsu Uranium Exploration Canada Ltd. (12.875%), and Korea Electric Power Corporation (2% non-voting).

At the Midwest project near South McMahon Lake in northern Saskatchewan, the results of a year-long test mining program, completed in October 1989, have been evaluated and an EIS has been prepared. The high-grade section of the deposit reportedly contains 12 500 tU grading over 5 per cent U. Denison (45%) operates the joint venture; the other partners include UEM (20%), Bow Valley Industries Ltd. (20%), and Overseas Uranium Resources Development

Figure 5. Canadian Uranium Production Capability Compared with Domestic Reactor Requirements



Source: Electricity Branch/EMR

Corporation (OURD) of Japan (15%). PNC Exploration (Canada) Co. Ltd. transferred its equity interest in the project to OURD during 1991.

In May 1990, Cameco announced the McArthur River discovery, 70 km northeast of Key Lake, in northern Saskatchewan. The high-grade deposit (P2 North), located at a depth of 500 to 550 m, has been drilled along strike for over 2 km. The best intersection returned 47 per cent U across 9 m, but grades up to 65 per cent U have been reported. The deposit reportedly contains resources exceeding 77 000 tU grading, on average, more than 3 per cent U. Follow-up evaluation continues, with development timing scheduled to coincide with the depletion of stockpiled ore at Key Lake. The major joint venture partners are Cameco (44%), UEM (29%), AGIP Resources Ltd. (10%) and Cogema (6.5%).

Minatco Limited's Wolly project, located adjacent to the Rabbit Lake property, hosts significant uranium mineralization, including the McClean, Jeb, and Sue deposits. Minatco is continuing exploration and development work at Wolly, and has completed an EIS in preparation for a production decision by the mid-1990s. The McClean deposits could be mined by underground methods, while the Jeb and Sue deposits are exploitable by open-pit methods. In late 1990, Minatco acquired 100 per cent of Wolly from joint venture partners Canadian Occidental Petroleum Ltd. and Canadian Nickel Company Limited.

In April 1991, the Minister of Energy, Mines and Resources referred six proposals for new uranium mining facilities in Saskatchewan for public review by an independent Panel, pursuant to the federal government's Environmental Assessment and Review Process (EARP) Guidelines Order. Five will be reviewed by a joint federal-provincial Panel, namely: the extension of the Cluff Mining operation by developing the South and West Dominique-Janine deposits, the Denison Midwest Joint Venture South McMahon Lake project, the Minatco McClean Lake project, the Cigar Lake Mining project at Cigar Lake, and the Cameco McArthur River project. The sixth proposal, an expansion of Cameco's Rabbit Lake operation by development of the Eagle Point/Collins Bay A & D deposits, will be reviewed by a federal-only Panel, because conditional approval has already been granted by Saskatchewan authorities.

In the Northwest Territories, the Kiggavik project of Urangesellschaft Canada Limited (UCL) had already been referred to an EARP Panel. However, in July 1990, UCL, the principal owner and operator of the project, requested that the Panel delay indefinitely its planned environmental assessment hearing for the Kiggavik project. The company indicated that more time was needed "to respond thoroughly to the request for considerable additional information", resulting from the Panel's earlier identification of deficiencies in its Environmental Assessment Report. The project is held by UCL (79%), CEGB Exploration (Canada) Ltd. (20%), and Daewoo Corporation (1%) of Korea.

Table 5. Proposed New Uranium Mining Projects

Project/Operator	Project type	EIS status	Deposit type
Collins Bay A & D and Eagle Point/Cameco	Expansion	Submitted	Unconformity
Dominique-Janine/Cluff Mining	Extension	Submitted	Unconformity
South McMahon Lake/Denison-Midwest JV	New Facility	Submitted	Unconformity
McClean Lake(Wolly)/Minatco	New Facility	Submitted	Unconformity
Cigar Lake/Cigar Lake Mining Corp.	New Facility	Not Prepared	Unconformity
McArthur River/Cameco	New Facility	Not Prepared	Unconformity
Kiggavik/Urangesellschaft	New Facility	Submitted	Unconformity

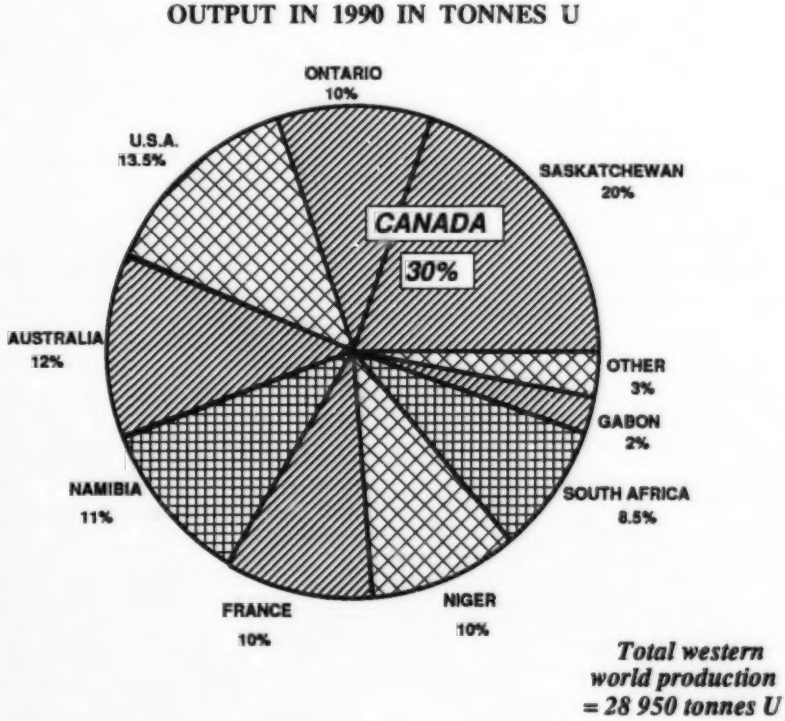
Other Developments

In July 1990, Rio Algom Mining Corporation (RAMC), the wholly-owned U.S. subsidiary of Rio Algom Limited, acquired about 8 per cent of the shares of Uranium Resources, Inc. (URI). RAMC owns uranium mining properties near Grants, New Mexico, and extensive in-situ leach (ISL) uranium properties in New Mexico and Wyoming; URI owns ISL uranium operations in South Texas, and undeveloped properties there and in New Mexico. Annual output of about 325 tU is expected from URI's Rosita solution mining operation in Texas, which began production in September 1990. In May 1991, an agreement was reached whereby RAMC would purchase all of the outstanding shares of URI for US$41 million. If this transaction is concluded, the combined entity would have total ISL uranium reserves in excess of 25 000 tU.

In December 1990, Denison announced the formation of a 50-50 joint venture with Freeport Uranium Recovery Company of the United States, effective January 1, 1991. Freeport produces uranium concentrates from its two existing phosphate processing plants in Louisiana, with a combined annual capacity in excess of 450 tU, and Denison markets them.

Figure 6 compares 1990 production of uranium in Canada with that of the other major western producers.

Figure 6. Western World Uranium Production, 1990



Source: Electricity Branch/EMR

2. REQUIREMENTS

A) Domestic Nuclear Power Program

In September 1990, Ontario elected its first New Democratic Party (NDP) government. Long believing that nuclear power should be phased out in favour of conservation, the NDP government deferred construction of new nuclear facilities. However, it was announced that construction at the four-unit Darlington station would be completed and the facility brought into operation to provide Ontario the security of electricity supply it needs for the future. Ontario Hydro was asked to "divert planned expenditures for new nuclear developments towards the most comprehensive energy conservation program ever undertaken by a utility in North America". Assessment of Ontario Hydro's 25-year energy demand/supply plan continues, with nuclear R&D maintained at agreed levels.

The determination of Canada's uranium requirements is based on the estimates of installed nuclear generating capacity shown in Table 6. As of January 1991, Canada's nuclear capacity in operation, or committed for operation by 1993, was some 15 400 megawatts electric net (MWe). In addition, a second Candu unit is envisaged for Point Lepreau, New Brunswick, another four Candu units could be built east of Toronto, at Darlington, and talks are underway toward a Candu 3 reactor in Saskatchewan. By the year 2000, total installed capacity in Canada could increase to 16 000 MWe.

Canadian policy on domestic security of uranium supply requires that sufficient uranium be reserved to meet the 30-year fuel requirements of all Canadian nuclear power reactors, existing, committed and planned, for a rolling 10-year period. The 30-year requirement for the reactor capacity noted above, assessed on the basis of fuel utilization design values for existing stations, is estimated to exceed 58 000 tU. The introduction of improved burn-up characteristics could reduce requirements by as much as 15 per cent. Annual requirements, including first cores for future reactors,

Table 6. Nuclear Power Plants in Canada[a].

Reactors	Owner	Net capacity (MWe)	In-service dates
Pickering 1 to 4	Ontario Hydro	2 060	1971-73
Bruce 1 to 4	Ontario Hydro	3 076	1977-79
Point Lepreau	NB Power*	635	1983
Gentilly 2	Hydro-Québec	638	1983
Pickering 5 to 8	Ontario Hydro	2 064	1983-86
Bruce 5 to 8	Ontario Hydro	3 394	1984-87
Darlington 1 to 4	Ontario Hydro	3 524	1990-93[e]
Total net capacity expected by 1993		15 391 MWe	

[a] *As of January 1991* [e] *expected*
* *The New Brunswick Electric Power Commission*

are now expected to grow from 1 900 tU/ year in 1991 to about 2 300 tU year in 2005, as shown in Table 7.

A measure of domestic uranium resource adequacy can be derived by comparing the 58 000-tonne domestic requirement described above with the conservatively adjusted[$] estimates of recoverable resources of all companies marketing Canadian uranium. The total of such resources currently exceeds by a reasonable margin the sum of the 30-year domestic requirement plus existing contract commitments. However, with the erosion of resources that will be more fully reflected in future assessments due to the planned premature Elliot Lake closures, the continued adequacy of this margin could depend very much on the outcome and timing of the environmental reviews of new mining projects in Saskatchewan. ([$]See Appendix 2.)

B) Uranium Sales Commitments

Canadian producers shipped (i.e., delivered to customers' accounts) about 9 720 tU in 1990 valued at $888 million. Some 80 per cent of this total was destined for the export market; the relative importance of Canada's uranium export customers is shown in Table 8. The average price of export deliveries in 1990 was about CAN$71/kgU. Less than 1 per cent of all export deliveries in 1989 and 1990 were spot sales, compared with some 13 per cent in 1988, 35 per cent in 1987, and 21 per cent in 1986.

Canada's short-term uranium needs are primarily those required for Ontario Hydro's nuclear power program. The utility's two major uranium supply contracts with Denison Mines Limited and Rio Algom Limited, approved by the Government of Ontario in February 1978, were renegotiated in 1991 (see also Existing Operations - Ontario). With the termination of these contracts in 1992 and 1996, respectively, Ontario Hydro will need to secure new sources of supply to cover its requirements beyond the mid-1990s. As of mid-1991, total outstanding domestic commitments were in the order of 7 000 tU, compared with some 70 000 a year earlier.

Table 7. Estimated Annual Canadian Uranium Requirements[e]

Year	Tonnes U	Year	Tonnes U
1991	1 900	1995	1 900
1992	1 900	2000	2 100
1993	1 900	2005	2 300

[e] *Estimated fuelling requirements for the nuclear power programs of Ontario Hydro, Hydro-Québec, and The New Brunswick Electric Power Commission.*

Table 8. Canadian Uranium Under Export Contract[a]

Country of buyer[b]	*Tonnes U*
Belgium	3 110
Finland	3 512
France	9 715
Germany [West]	14 994
Italy	1 115
Japan	27 181
South Korea	6 830
Spain	3 559
Sweden	9 475
Switzerland	154
United Kingdom	7 639
United States	72 924
Total	160 208

[a] *The nominal quantity of uranium in all export contracts reviewed and accepted under Canadian uranium export policy since September 5, 1974. Country totals are adjusted to reflect new contracts, contract amendments, and the exercising of quantity-flexibility options, as of January 1, 1991.*

[b] *In most cases, indicates country of end-user.*

Total forward export commitments exceed 60 000 tU, to be delivered in the period 1991 to 2003. Actual 1990 exports were 8 648 tU, down slightly from 9 398 tU in 1989 and 10 434 tU in 1988; as has been the case for several years, the United States, Western Europe and Japan receive the bulk of Canada's uranium exports, as shown in Table 9.

Japan, the largest market for uranium in East Asia, has to date acquired the major portion of its uranium requirements from Canada. In fact, Japan has been Canada's largest single uranium customer since the beginning of the commercial nuclear era in the mid-1960s. Other important markets are the European Economic Community, other Western European countries and, increasingly, the United States. Indeed, in terms of forward scheduled commitments, the U.S. is now Canada's major customer as shown in Figure 7 on the following page. Over the past five years, the United States has received about 45 per cent of Canada's uranium exports. In 1990, U.S. utilities negotiated the bulk of the some 8 000 tU in new export sales volume with Canadian producers, much of it under long-term contract. Such long-term commitments are important to the viability of Canada's uranium industry.

c) Short-Term Market Outlook

The uranium market has suffered from oversupply since the late 1970s, when surplus inventories began to accumulate due to delays and cutbacks in reactor construction, and declines in new reactor orders. Although reactor-related requirements have exceeded production since 1985, the drawdown of excess utility inventories has been slower than expected and a significant surplus still overhangs the market. The oversupply situation has been exacerbated recently by

Table 9. Exports of Uranium of Canadian Origin

Final destination	Tonnes of contained uranium[a]					
	1985	1986	1987	1988	1989	1990
Belgium	157	63	-	153	190	-
Finland	81	116	142	151	71	83
France	612	1 013	1 438	964	696	799
Germany [West]	269	654	1 317	806	615	220
Indonesia	-	-	-	-	1	-
Italy	53	301	293	-	46	-
Japan	1 799	816	1 317	717	1 729	2 005
Netherlands	-	85	40	-	-	-
South Korea	194	402	828	874	635	339
Spain	-	150	150	100	97	-
Sweden	514	449	377	783	497	285
Turkey	-	2	-	-	-	-
United Kingdom	685	700	824	1 204	871	882
United States	3 524	3 692	6 063	4 682	3 950	4 035
Total	7 888	8 443	12 789	10 434	9 398	8 648

[a] *Some of this uranium was first exported to intermediate countries, e.g., France, U.S.A. and U.S.S.R., for enrichment and then forwarded to the country of final destination.*

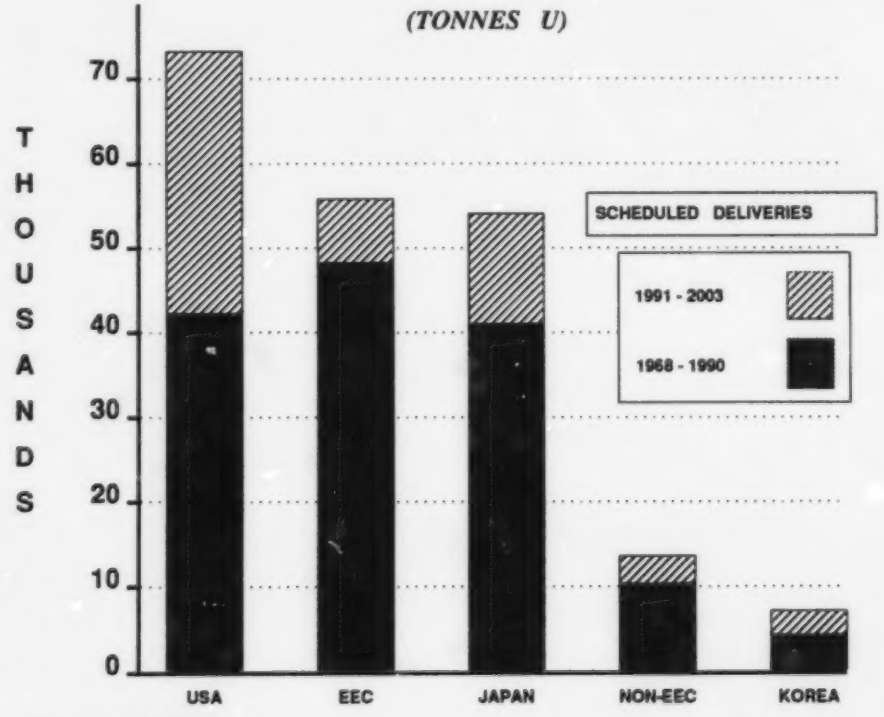
Source: Atomic Energy Control Board

the availability of low-priced uranium from the German uranium stockpile and from non-traditional suppliers, especially the U.S.S.R., certain Eastern European countries and China. In addition, broker/traders have become increasingly active, moving excess supplies into the market and thus contributing to increased spot-market price volatility. In 1990, for example, the NUEXCO Exchange Value slid to US$8.70/lb U_3O_8 by February, jumped to US$11.70 in July, fell to a record low of US$8.35/lb U_3O_8 in October and recovered to US$9.70/lb U_3O_8 at year end.

The latest edition of *Nuclear Energy Data* (the "Brown Book"), published by the Nuclear Energy Agency (NEA) of the OECD, indicates that OECD uranium requirements alone will increase from about 41 000 tU in 1990 to 50 000 tU in 2010, by which time Western world uranium production capability will have fallen from the current 33 000 tU to only 24 000 tU. [7] Clearly, this level of requirements cannot be met by output from existing and committed production centres relying on lower-cost resources.

As a result, most market analysts have estimated that new production facilities will be required in the mid-1990s. However, while output from planned and prospective production centres can be made available, the emergence of non-traditional suppliers and the availability of surplus inventory suggests that the need for new sources of uranium production could be delayed significantly. The timing of many of these new projects could well depend on the supply-diversification strategies of the world's nuclear utilities.

Figure 7. Scheduled Deliveries of Canadian Uranium for the Export Market



Source: Electricity Branch/EMR

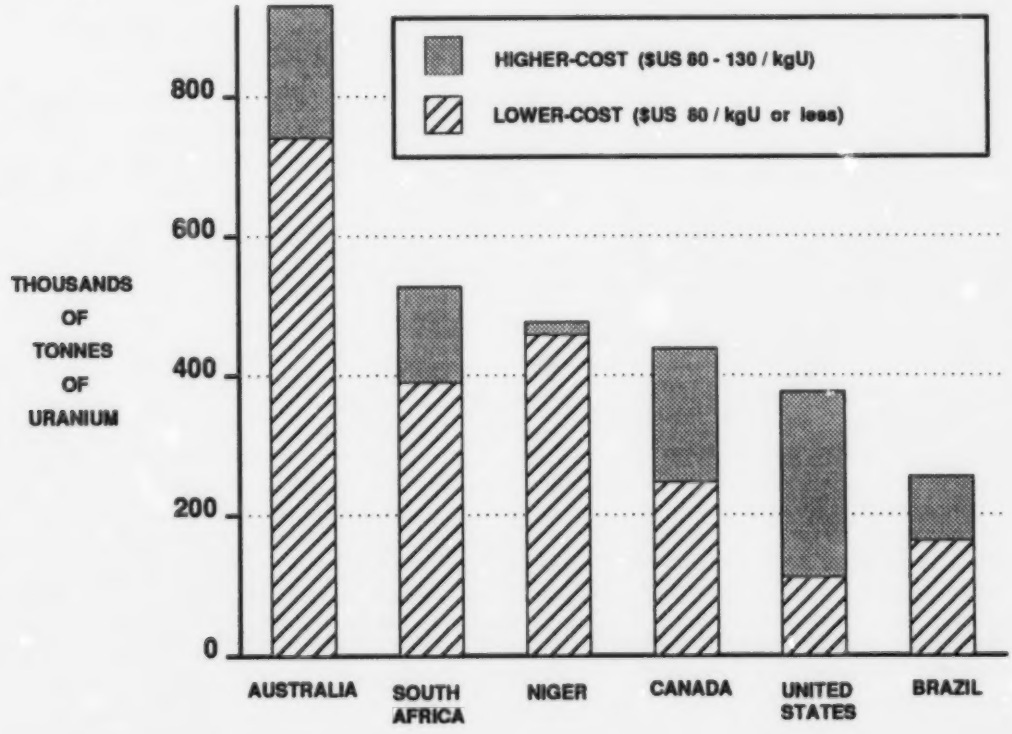
Part II. LONGER-TERM PERSPECTIVE

1. SUPPLY

A) Supply Sources

The resources described in Part 1 of this report will provide a base for Canadian production beyond the turn of the century. Although the deposits at some existing production centres will have been depleted by that time, the resources associated with others are sufficient to permit production beyond the end of the century. Importantly, the planned closure of Denison's operation in 1992 and Rio Algom's Stanleigh operation in 1996 means that the remaining Elliot Lake uranium resources are unlikely to be economically recoverable by conventional methods in the near future. However, several recent Saskatchewan discoveries might be developed for production before the end of the century should market conditions warrant. Figure 8 compares estimates of Canada's known uranium resources with those in other producing countries.

Figure 8. Estimates of Known Uranium Resources in Selected Countries



Source: NEA/IAEA "Red Book", Paris 1990

Beyond these resources, Canada has significant potential for additional discoveries. It is important to emphasize the distinction between the two categories of 'undiscovered' resources, namely prognosticated and speculative. The first refers to uranium that is expected to exist in well-defined geological trends containing known deposits. The speculative category refers to uranium that is thought to exist in unexplored areas or in areas where only occurrences are known. A relatively higher degree of confidence can be placed in estimates of the first type of undiscovered resources because of their proximity to, or close association with, well-delineated deposits.

Prognosticated Resources

Estimates of Canada's prognosticated uranium resources as of 1/1/91 are presented in Table 10, together with those as of 1/1/89. The latest URAG assessment of prognosticated resources indicates a 20 per cent decrease in the overall estimate; the drop in the lower ("A") price category exceeded 55 per cent. The decline reflects continued exploration in the Athabasca Basin of Saskatchewan (see Part 1) and the consequent transfer of resources from the prognosticated to the inferred category of resources as they become better delineated. As is evident from the concentration of new discoveries in the Athabasca Basin, the Proterozoic unconformity-related type deposits remain the primary exploration targets.

Speculative Resources

Many other areas of Canada are favourable for the occurrence of uranium resources, in addition to those associated with known uranium deposits. In the current assessment, some resources in the speculative category were moved into the "better-defined" categories, while other resources were removed as being uneconomic in the foreseeable future. Transfers to the better-defined categories were primarily in the Athabasca Basin region [related to the identification of resources on the McArthur River block and Carswell Structure]; in the past two years, transfers represent a 10 per cent loss in the speculative category. However, favourable new areas have been discovered, but most of these contain very low-grade mineralization that would be recoverable only at prices exceeding CAN$300/kgU. Estimates made for the current assessment, therefore, show that speculative resources in Canada have been reduced to about 900 000 tonnes of uranium.

Table 10. Estimates of Canada's Prognosticated Resources of Uranium Contained in Mineable Ore[a]

Price ranges within which mineable ore is assessed[b]	Thousands of tonnes of uranium	
	1/1/91	1/1/89
A	68	154
B	122	120
C	117	107
A + B + C	307	381

[a] *Uranium recoverable from such ore will be less because of ore-processing losses.*

[b] *Price ranges are (A) $100/kg U or less, (B) $100 to $150/kg U, and (C) $150 to $300/kg U.*

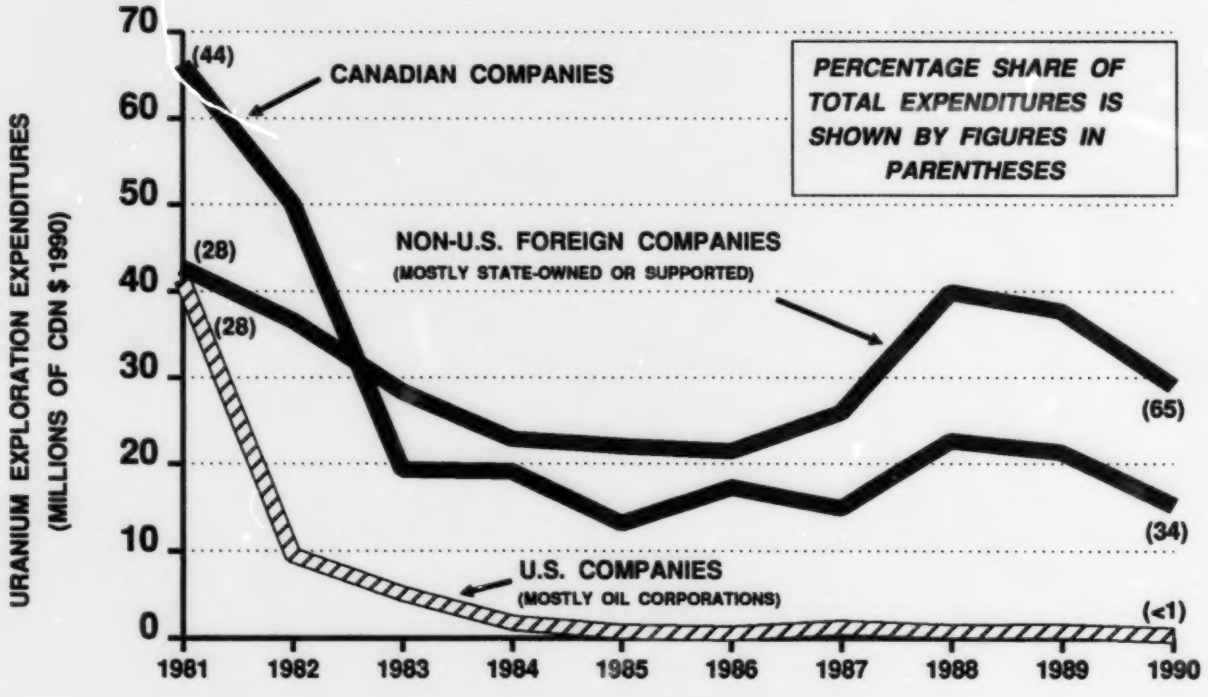
Estimates of speculative resources are based on Canada's past production, on distribution of known uranium deposits, and on interpretation of geological features according to conceptual models [8/9]. They are deemed to be geologically comparable to resources in known deposits that could be mined at a price of $300/kg U or less. Further resources might exist in areas that have not been assessed. Most of the speculative resources are believed to occur in unconformity-related deposits. Additional new uranium-bearing regions may be outlined in Canada as a result of further studies on geologically similar areas outside Canada.

Uranium Exploration Activities

In 1988 and 1989, total annual uranium exploration expenditures in Canada approached $60 million, up sharply from the $32 to $37 million range between 1984 and 1987. [10] This increase was related mainly to the advanced underground exploration efforts at the Cigar Lake project in Saskatchewan, where shaft sinking was underway in preparation for test mining; actual surface (grass-roots) exploration expenditures for uranium declined, and in Saskatchewan were down 30 per cent in 1989. In 1990, uranium exploration expenditures in Canada approached $45 million, with a significant percentage of the total accounted for by underground geotechnical testing at Cigar Lake; grass-roots exploration dropped sharply again in 1990.

Figure 9 illustrates the trend in corporate participation in uranium exploration in Canada. Foreign-based companies accounted for an increasing share of total

Figure 9. Trend in Uranium Exploration Expenditures in Canada



Source: Electricity Branch/EMR

expenditures in Canada through the 1980s, lately spending about two-thirds of the total annual outlay. While foreign involvement in uranium exploration in Canada is high and has been increasing, participation by U.S. firms has steadily decreased since 1984 to less than 1 per cent in 1990. Although it appears that this trend could continue, the obvious geological advantages for discovering uranium in Canada, the benefits of the Free Trade Agreement, and Canada's liberalized uranium non-resident ownership policy could help reverse the trend in the 1990s.

Table 11. Uranium Exploration Activity in Canada, 1976 to 1990*

	Total spent[a] ($million)[b]	Total drilled[c] (km)	Million-dollar Projects[d]
1976	44	155	4
1978	90	334	7
1980	128	503	24
1982	71	247	13
1984	35	197	12
1986	33	162	11
1988	59	201	11
1989	58	158	11
1990	45	66	6

* *Refer to Appendix 1 for more exploration activity data.*

[a] *Direct exploration and drilling expenditures*

[b] *Current (reporting year) dollars*

[c] *Exploration and surface development drilling; excludes development drilling on producing properties*

[d] *Number of projects where total expenditures exceeded $1 million*

In 1989, 13 operators* managed 57 active projects, in which 30 companies participated. In 1990, about 27 companies participated in 33 active projects, managed by just twelve operators. The ten most active of these in 1990, spending virtually the total $45 million, were, in alphabetical order, Amok Ltd., Cameco Corporation, Cigar Lake Mining Corporation, Cogema Canada Limited, Interuranium Canada Limited, Minatco Ltd., PNC Exploration (Canada) Co. Ltd., Rio Algom Exploration Inc., Uranerz Exploration and Mining Limited (UEM), and Urangesellschaft Canada Limited. [*In most cases, operators report the total expenditures of a joint-venture and thus contributions by other parties are accounted for in the total.]

Seven of these ten operators are companies whose majority interests are held outside of Canada; several of those are supported, directly or indirectly, by their national governments in their uranium exploration efforts.

While exploration and surface development drilling jumped 22 per cent in 1988 to over 200 000 m, as efforts became centred on the developed and proven properties, drilling activity in 1989 decreased by 20 per cent as exploration was further concentrated on properties with development potential. However, in 1990, drilling efforts were more than halved, due to the market situation, with only 66 000 m of exploration and surface development drilling completed compared to 158 000 m in 1989.

Table 11 summarizes recent uranium exploration activity in Canada, and shows that until the 1990/91 exploration season the number of "million-dollar" projects has remained relatively constant since 1982. [10]

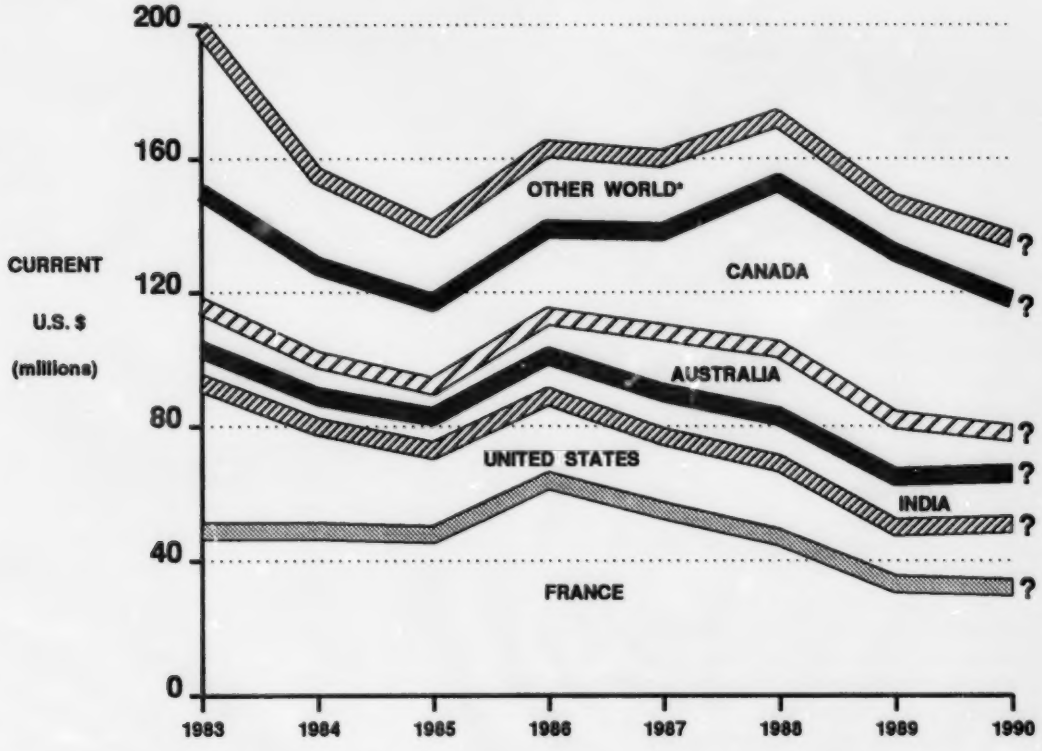
Recent NEA/IAEA "Red Books" [1989] have shown that while uranium exploration expenditures have declined in several countries since the early 1980s, Canada's share of total Western world uranium exploration expenditures has remained relatively constant. [11] A comparison of uranium exploration expenditures in selected countries from 1983 to 1989 is shown in Figure 10.

In 1990/91, uranium exploration efforts in Saskatchewan were again focussed in the Athabasca Basin, along the Cigar Lake/Key Lake structural trend and its northeastern extension, on the Wolly Block around the Collins Bay Dome, and on the western part of the Basin. In the Northwest Territories, the greatest effort was conducted along the Kiggavik structural trend in the Thelon Basin. (See Fig. 1.)

Many exploration programs in Saskatchewan are based on the application of conceptual genetic models, postulating deposit association with Proterozoic unconformities and with granitic basement domes. Of particular interest in the 1989/90 field season was the grass-roots exploration activity conducted near Great Bear Lake, Northwest Territories, which was sparked as a result of deposit-origin investigations by the Geological Survey of Canada. This work established a conceptual model indicating that deposits comparable to the Olympic Dam copper, gold, uranium orebody in Australia may be discovered in the area.

The 1990/91 field season was highlighted by significant increments in higher-grade uranium resources, most notably in Saskatchewan at the McArthur River and Wolly projects, and in the Northwest Territories along

Figure 10. Uranium Exploration Expenditures in Selected Countries



** World, as used here, excludes the U.S.S.R., Eastern Europe, and the People's Republic of China.*

Source: Electricity Branch/EMR

the Kiggavik structural trend. These additions more than compensated for the loss of low-grade resources in 1990 resulting from developments at Elliot Lake, Ontario. As noted in Part 1, in 1990, Cameco announced the discovery of high-grade mineralization at McArthur River, northern Saskatchewan, (see Fig. 1). The best intersection returned 47 per cent U across 9 m, with grades up to 65 per cent U. Resources are estimated to contain over 77 000 tU grading in excess of 3 per cent U on average. Follow-up evaluation of the deposit continues, with development timing scheduled to coincide with the depletion of stockpiled ore at Key Lake.

B) Uranium Availability [12]

Uranium availability in the longer term will be dependent on a number of factors, the most important of which will be a continuing and developing demand for uranium and an orderly development of the international uranium market. In addition, all new proposed uranium production centres in Canada will be subjected to increasingly comprehensive environmental assessments before being granted regulatory approval.

Known deposits associated with existing, planned and prospective uranium production centres in Canada are capable of supporting significant output levels well beyond 2000. An appreciation of the long-term availability of uranium from these deposits can be obtained by extending the short-term projections detailed in Part 1 of this report. Based on existing production centres only, and relying on resources recoverable at uranium prices of $150/kgU or less, it can be projected that Canada's production capability will decline steadily, likely falling below 5 000 tU beyond the year 2010.

However, additional capability could come from new production centres that might be brought on-stream given favourable developments in the uranium market, including a significant recovery in price. If additional uranium output from the planned and prospective centres is included in such projections, production capability could be maintained at or somewhat above current levels beyond the year 2010.

On the other hand, if production is to significantly exceed current levels, it must come from new discoveries, the realization of which would involve considerable exploration and development effort. Uncertainties about the development of the international uranium market, as well as the costs associated with certain of the planned and prospective projects noted in Part 1, make it difficult to project production capability levels very far into the future with any degree of precision.

In a recent study on the impact of taxation on uranium mining in Canada and Australia (see Mackenzie, et al), it was demonstrated quite clearly that under present market conditions, only the best uranium mining projects will have a chance of being developed. [4] Moreover, the costs of development of new projects will inevitably increase as a result of more stringent environmental regulations with respect to radiation protection and safety. Recent recommendations of the International Commission on Radiological Protection (ICRP) that would lower the radiation dose limits for atomic radiation workers*, if adopted by the AECB, could pose difficulties for some uranium producers. Taking all such considerations into account, it is clear that the economic justification of uranium exploration will require quite exceptional targets.

It is also important to appreciate the long lead-times and inherent risks that are associated with uranium exploration activities. It is not uncommon that 15 years elapse between the start of an exploration program and first production from a successful discovery. With this in mind, current exploration programs should be focussed on meeting the longer-term needs of Canada and its trading partners. A loss of exploration momentum now could jeopardize supply opportunities beyond the turn of the century.

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* *The ICRP recommended that the effective dose limit for atomic radiation workers be lowered from the current 50 milliSievert/annum (mSv/a) to 20 mSv/a averaged over five years.*

2. REQUIREMENTS

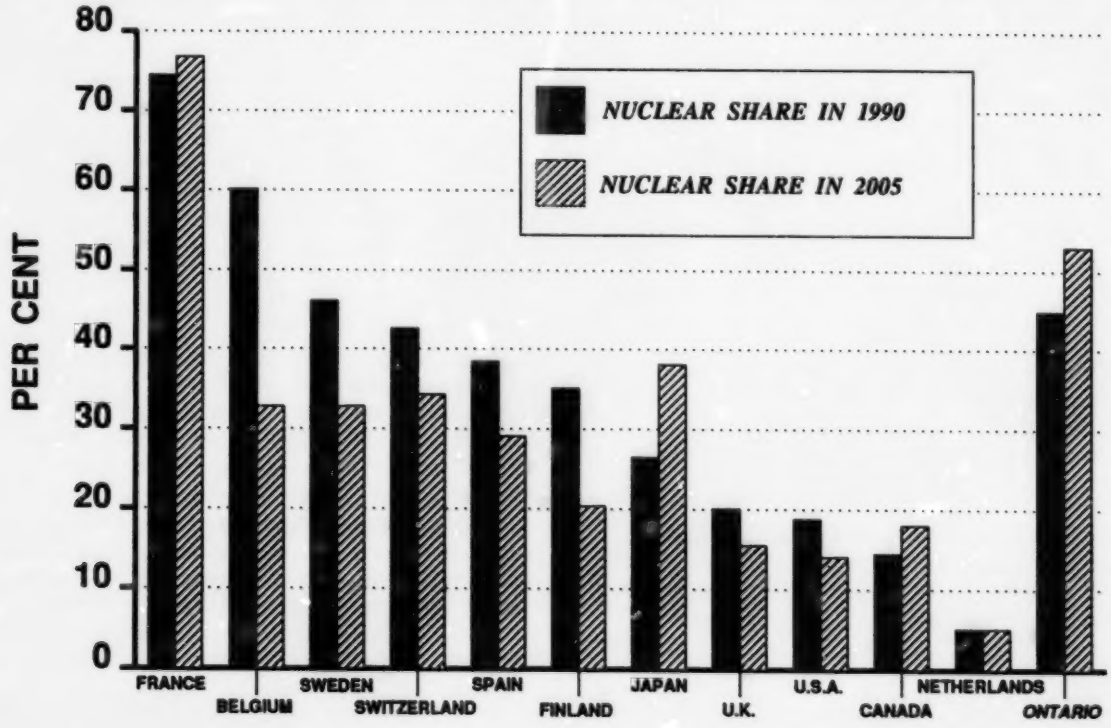
A) World Outlook for Nuclear Power Growth*

Future requirements for Canadian uranium will depend on the growth in nuclear power capacity in the electricity generating systems of Canada and its trading partners.

Projections of installed nuclear power capacity have been revised downward in recent years as a result of the competition from coal and gas, efforts to introduce energy conservation measures in several countries, and negative public opinion. However, forecasts continue to reflect steady growth in the contribution that nuclear power will make to world electricity supply, as shown in Figure 11. [7/11]

* *World, as used here, excludes the U.S.S.R., Eastern Europe and the People's Republic of China.*

Figure 11. Nuclear Share of Electricity Generation in Selected Countries, 1990 and 2005



Source: OECD and Ontario Hydro

In September 1990, the IAEA reported that global consumption of electricity was projected to grow at an annual rate exceeding 3 per cent, with nuclear-electric generation increasing at just less than 3 per cent per annum. At year end 1990, it was noted that since 1986, the year of the Chernobyl accident, more than 80 new nuclear plants have been brought on line worldwide, a quarter of those in 1989 and 1990. In April 1991, the IAEA's Power Reactor Information System (PRIS) reported that 83 nuclear reactors were under construction as of January 1, 1991, in addition to the 423 reactors already in operation world-wide. In just 30 years, nuclear power's share of total world electricity generation has risen from less than 1 per cent to about 17 per cent.

Beyond 2000, the future of nuclear power may be affected by decisions taken in the next few years with regard to the environment. The growing awareness that nuclear power plants contribute little to global warming, and rising concern about the emission of CO_2 and other "greenhouse" gases may result in increased orders for nuclear power plants. In France, for example, where nuclear plants now generate 75 per cent of all electricity, emissions of CO_2 have fallen steadily over the past decade as nuclear's share of total electricity generation has risen. In Sweden there has been a clear change in attitude, whereby the major political parties have reconsidered the 1988 decision to close two of the country's twelve nuclear power reactors by 1996.

Canada's total installed nuclear capacity in the year 2000 is expected to reach 16 000 MWe requiring about 2 100 tU per year. Nuclear energy will then be providing about 16 per cent of the electricity supply in Canada and about half in Ontario.

The IAEA's PRIS data also indicated that installed nuclear power capacity in the world reached 326 000 MWe (net) as of January 1, 1991. The OECD estimates that installed capacity in its member states alone will grow from 262 000 MWe (as of 1/1/91) to about 324 000 MWe in 2010. The actual rate will depend upon economic growth and the related electricity requirements, and on the extent to which nuclear power is able to penetrate the electricity market. As noted previously, related uranium requirements in the OECD could rise from the current annual level of 41 000 tU to about 50 000 tU by the year 2010. [11]

B) Demands on the Uranium-Producing Industry

Canada is the world's leading supplier of uranium, and is among the leaders in terms of estimated uranium resources in all categories. Canada accounts for a significant proportion of the world's low-cost known resources. (See Fig. 8.)

Canada's uranium producers are adjusting to the volatile market conditions of recent years, and are prepared for the challenge of the 1990s. Producers have trimmed output levels, some have purchased uranium on the spot market and one has been forced to close two production facilities. Two more operations face closure in 1992 and 1996, respectively. On the other hand, development work is proceeding on several new uranium projects. Canada has the uranium resources, infrastructure, and determination to remain a reliable and competitive supplier of uranium for many years to come.

The NEA/IAEA's most recent assessment of world uranium supply illustrates that Canada is one of the most promising countries for the discovery of additional uranium resources. [11] Canada has been a reliable uranium supplier to the world market for more than 40 years, and the Canadian government is committed to maintaining that role. Given its production capabilities and potential for additional discoveries, there is every reason to be confident that Canada can maintain its leading role in the world uranium market, while continuing to supply its domestic needs.

APPENDICES

APPENDIX 1: URANIUM EXPLORATION STATISTICS

A. Uranium Exploration Drilling and Surface Development Drilling Activity in Canada*, 1981 to 1990

Province or territory	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*
	(thousands of metres)									
Saskatchewan	300.7	213.5	120.5	165.8	164.4	153.9	153.2	184.2	146.1	55.9
Northwest Territories	22.6	21.5	17.6	17.1	17.2	3.9	5.5	9.6	6.9	6.8
Quebec	18.5	12.4	13.4	14.1	1.7	0.0	0.0	0.0	0.0	0.0
Nova Scotia	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ontario	3.0	0.0	1.4	0.0	0.0	0.0	1.1	2.0	0.8	0.0
New Brunswick	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Newfoundland	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manitoba	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alberta	0.6	0.0	0.0	0.0	0.0	4.3	4.2	5.9	4.0	3.7
Yukon Territory	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
British Columbia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unspecified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals (rounded)	359	247	153	197	183	162	164	202	158	66

**'Exploration drilling' refers to drilling done in search for new uranium deposits or extensions to known uranium deposits and to drilling at the location of a discovery up to the time that the company decides that sufficient ore has been delineated to justify commercial exploitation.*

'Surface development drilling' refers here to drilling subsequently done to determine more precisely a deposit's size, grade and configuration, and excludes development drilling on producing properties.

APPENDICES

APPENDIX 1: URANIUM EXPLORATION STATISTICS

B. Uranium Exploration Expenditures in Canada*, 1981 to 1990

Province or territory	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*
	(millions of current Canadian dollars)									
Saskatchewan	60.8	47.9	27.3	24.8	23.5	28.9	32.7	50.1	51.2	40.7
Northwest Territories	23.6	13.2	7.3	6.4	6.2	2.5	2.7	6.5	5.3	3.0
Quebec	8.8	8.4	5.6	3.3	1.0	0.05	0.0	0.0	0.0	0.0
Nova Scotia	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Newfoundland	1.6	0.3	0.4	0.4	0.3	0.0	0.05	0.0	0.0	0.0
Ontario	0.9	0.4	0.2	0.0	0.0	0.0	0.1	0.3	0.1	0.0
New Brunswick	0.8	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yukon Territory	0.7	0.3	0.0	0.06	0.2	0.2	0.0	0.0	0.0	0.0
Manitoba	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alberta	1.1	0.0	0.0	0.06	0.4	0.8	1.4	1.7	1.3	0.9
British Columbia	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.09	0.0	0.0
Unspecified	0.5	0.0	0.0	0.06	0.2	0.07	0.1	0.0	0.1	0.0
Totals (rounded)	102	71	41	35	32	33	37	59	58	45

**Expenditures on exploration and surface development drilling and all other costs directly associated with uranium exploration activities, excluding land acquisition. Overhead charges not directly associated with such activities are not included.*

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APPENDIX 1: URANIUM EXPLORATION STATISTICS

C. Total Expenditures and Coverage of Government-Sponsored Radiometric and Geochemical Surveys

Year	*Area covered*		*Expenditures*[a]		
	Radiometric	Geochemical[b]	Radiometric	Geochemical	Total
	(km^2)		*($ million)*		
1975-1982*	2 116 000[c] 56 000[d]	1 323 000	10.084	10.597	20.681
1983	19 500[c] 22 500[d]	99 000	0.397	0.784	1.181
1984	75 500[c] 22 000[d]	96 000	0.616	0.647	1.263
1985	34 000[d]	160 400	0.640	1.138	1.778
1986	57 000[c] 25 500[d]	184 100	0.738	1.568	2.306
1987	15 500[d] 1 600[e]	143 000	0.450	1.854	2.304
1988	13 000[d] 6 500[e]	108 900	0.550	1.538	2.088
1989	17 700[d] 2 300[e]	51 700	0.475	0.840	1.315
1990	21 500[d] 4 600[e]	57 000	0.540	0.930	1.470
1991[f]	17 700[d] 2 600[e]	35 000	0.550	1.000[g]	1.550
Total	2 531 000	2 258 000	15.04	20.896	35.936

[a] *In $Cdn for the survey year, includes federal and provincial funding. Government expenditures on exploration drilling are nil.*

[b] *Includes provincial surveys to National Geochemical Reconnaissance (NGR) standards.*

[c] *5-km line spacing*

[d] *1-km line spacing*

[e] *Less than 1-km line spacing*

[f] *Estimate*

[g] *Cost includes re-analysis of samples collected previously*

* *Pre-1975 data not reported*

Note: It should be noted that these surveys have been designed since their inception for the purpose of assisting mineral exploration and geological mapping in general, in addition to their specific relevance to uranium.

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APPENDIX 2

DEFINITIONS OF RESOURCE AND PRODUCTION TERMINOLOGY

In its annual uranium resource assessment, the Uranium Resource Appraisal Group (URAG) divides its estimates into five separate categories reflecting different levels of confidence in the quantities reported. These categories are further separated into three levels of exploitability related to the current uranium price.

The following definitions and terms used by URAG are in harmony with those used by Energy, Mines and Resources Canada (EMR) for non-fuel mineral and coal resource assessment.

Ore	A natural mineral-bearing substance that can be recovered by mining and from which one or more commodities can be extracted economically under conditions specified at the time of the appraisal.
Measured ore	Refers to ore for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, or drill-holes, and for which grade is computed from adequate sampling. The sites for inspection, sampling and measurement are so closely spaced and the geological character is so well defined that the size, shape and mineral content are well established. The tonnage and grade should refer to ore recoverable by mining with due regard for dilution.
Indicated ore	Refers to ore for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geological evidence. The openings or exposures available for inspection, measurement and sampling are too widely or inappropriately spaced to outline the ore completely or to establish its grade throughout.
Inferred ore	Refers to ore for which quantitative estimates are based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. Estimates are based on assumed continuity or repetition for which there is geological evidence; this evidence may include comparison with deposits of similar types. Bodies that are completely concealed, but for which there is some geological evidence, may be included. Estimates of inferred ore should include a statement of the specific limits within which the inferred material may lie. These limits vary depending upon the characteristics and knowledge of the orebodies.
Prognosticated resources	Refer to estimated tonnages beyond specific limits established for inferred ore. They may include tonnages of portions of identified orebodies or of concealed satellite orebodies, the existence of which can be assumed along well-established geological trends associated with known deposits. The attributes of prognosticated resources are, as a rule, derived by extrapolation from identified deposits or by quantification of geological information.

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Speculative resources	Refer to estimated tonnages in deposits thought to exist on the basis of indirect indications and geological extrapolations in unexplored areas or in areas where only occurrences are known. These resources would be geologically comparable to resources in known deposits that are judged to be mineable at prices below a given level.
Reserves	Refer only to those measured and indicated resources that could be mined at the uranium market price as determined at the time of the assessment (equivalent to block 1A of Figure A-1) unless another price is specified.
Adjusted recoverable resources	Refer to the sum of resources in the measured, indicated and inferred categories, weighted by factors of 1.0, 0.8 and 0.7, respectively, recoverable from mineable ore at prices of $150/kg U or less. The term was developed for the purpose of monitoring domestic uranium resource adequacy, and, as such, factors in only those resources of Canadian producers that are marketing uranium.

For categorization by price level (i.e., level of economic exploitability), cut-off grades are chosen that cover all costs of production after due consideration of processing losses, plus any required forward capital costs. The difference between the cut-off grade and the average grade of the resources for each individual deposit is then examined to determine if the difference is sufficient to carry such items as taxes and royalties, head office overhead, forward exploration and development costs, and an acceptable rate of return on invested capital (i.e., costs associated with the use of capital). If the difference between the chosen cut-off grade and the average grade is judged sufficient, the tonnage is taken to be mineable at a price below the stated limit.

Except where otherwise stated, resource estimates in the measured, indicated and inferred categories refer to quantities of uranium recoverable from mineable ore, as opposed to quantities of uranium contained in mineable ore, or uranium contained in-situ (i.e., deductions have been made for both mining and ore processing losses). In the case of the prognosticated category, resource estimates are expressed in terms of quantities of uranium contained in mineable ore. Speculative resource estimates are expressed as in-situ quantities.

For national and international purposes, Canadian resource estimates are often quoted in terms of the international uranium resource definitions employed by the NEA and the IAEA, in their assessments of world uranium resources, which are prepared as a joint exercise on a regular basis. The terms Reasonably Assured Resources (RAR) and Estimated Additional Resources (EAR) and their definitions were first developed in 1964, and have been retained with some modifications since then. It is pertinent to note that, in 1975, the NEA/IAEA changed its resource definitions to refer to 'cost' instead of 'price', while Canada has retained the price classification.*

The term Speculative Resources was introduced by the NEA/IAEA in 1978, in the recognition that assessments covering only RAR and EAR represented an incomplete appraisal of the world's uranium resources. In late 1982,

* *For purposes of international comparison, Canada's three defined 'price' categories may be considered equivalent to the NEA/IAEA's three defined 'cost' categories, from the lowest to the highest, respectively. The three defined cost/price categories are illustrated by blocks labelled A, B and C, respectively, in Figure A-1.*

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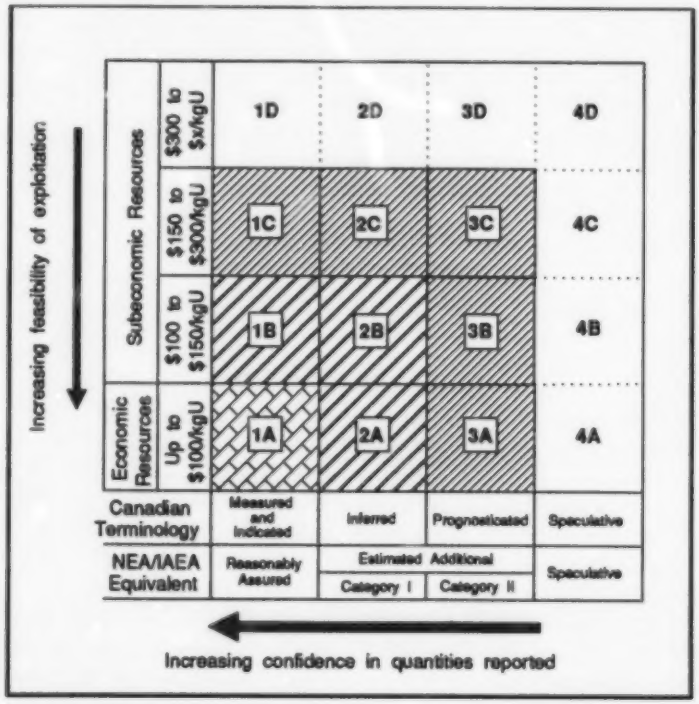
the NEA/IAEA redefined its EAR category to distinguish between the discovered and the undiscovered components of those additional resources that are expected to occur in association with known deposits. These two components have been termed Estimated Additional Resources - Category I (EAR-I) and Estimated Additional Resources - Category II (EAR-II), respectively.

The NEA/IAEA resource definitions shown below include minor editorial changes that were adopted by the NEA/IAEA for their 1989 exercise. The relationship of these definitions to those used in EMR's annual assessment of uranium resources is illustrated in Figure A-1.

Figure A-1. Classification Scheme for Resources of Recoverable Uranium



Source: NEA/IAEA and EMR

Reasonably Assured Resources (RAR)

Refers to uranium that occurs in known mineral deposits of delineated size, grade and configuration such that the quantities which could be recovered within the given production cost ranges, with currently proven mining and processing technology, can be specified. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits and on knowledge of deposit characteristics. Reasonably Assured Resources have a high assurance of existence.

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Estimated Additional Resources - Category I (EAR-I)	Refers to uranium in addition to RAR that is inferred to occur, mostly on the basis of direct geological evidence, in extensions of well-explored deposits, or in deposits in which geological continuity has been established but where specific data, including measurements of the deposits, and knowledge of the deposits' characteristics are considered to be inadequate to classify the resource as RAR. Estimates of tonnage, grade and cost of further delineation and recovery are based on such sampling as is available and on knowledge of the deposit characteristics as determined in the best-known parts of the deposit or in similar deposits. Less reliance can be placed on the estimates in this category than on those for RAR.
Estimated Additional Resources - Category II (EAR-II)	Refers to uranium in addition to EAR-I that is expected to occur in deposits for which the evidence is mainly indirect and which are believed to exist in well-defined geological trends or areas of mineralization with known deposits. Estimates of tonnage, grade and cost of discovery, delineation and recovery are based primarily on knowledge of deposit characteristics in known deposits within the respective trends or areas and on such sampling, geological, geophysical or geochemical evidence as may be available. Less reliance can be placed on the estimates in this category than on those for EAR-I.
Speculative Resources (SR)	Refers to uranium, in addition to EAR-II, that is thought to exist, mostly on the basis of indirect evidence and geological extrapolations, in deposits discoverable with existing exploration techniques. The location of deposits envisaged in this category could generally be specified only as being somewhere within a given region or geological trend. As the term implies, the existence and size of such resources are highly speculative.

In presenting their definitions, the NEA/IAEA emphasizes that the distinctions drawn between the four categories of resources (RAR, EAR-I, EAR-II and SR), based on differing degrees of geological evidence, make it essential that each category be regarded as a discrete entity. Therefore, great care should be taken in the use of resource estimates (e.g., not summing estimates of all four categories to obtain 'total resources'). For their 1989 assessment, the NEA/IAEA adopted the following two geological terms:

Uranium occurrence	Is a naturally occurring anomalous concentration of uranium.
Uranium deposit	Is a mass of naturally occurring mineral material from which uranium could be exploited at present or in the future.

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With the increased emphasis that has been placed on projections of production capability as illustrations of uranium supply possibilities, it was necessary to formalize a number of terms used in the description of such projections. The NEA/IAEA introduced the following terms in its December 1983 assessment of world uranium supply. These terms are used throughout this report.

Production centre

As referred to in this report, is a production unit consisting of one or more ore processing plants, one or more associated mines and the resources that are tributary to them. For the purpose of describing production centres, they have been divided into four classes, as follows:

A) **Existing Production Centres** are those that currently exist in operational condition and include those plants which are closed down but which could be readily brought back into operation.

B) **Committed Production Centres** are those that are either under construction or are firmly committed for construction.

C) **Planned Production Centres** are those that are planned, based on feasibility studies that are either completed or underway, but for which construction commitments have not yet been made. This class also includes those plants that are closed which would require substantial expenditures to bring them back into operation.

D) **Prospective Production Centres** are those that could be supported by tributary RAR and EAR-I, i.e.,'known resources', but for which construction plans have not yet been made.

Production capacity

Denotes the nominal level of output, based on the design of the plant and facilities over an extended period under normal commercial operating practice.

Production capability

Refers to an estimate of the level of production that could be practically and realistically achieved under favourable circumstances from the plant and facilities at any of the types of production centres described above, given the nature of the resources tributary to them. (Normally, projections of production capability are supported only by RAR and/or EAR-I.)

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APPENDIX 3

CANADIAN URANIUM EXPORT POLICY

Canadian uranium export policy has been designed and modified over the years with the primary objective of maintaining Canada's role as a reliable and competitive long-term supplier to its trading partners, while seeking to obtain optimum benefit for Canada from the development of its uranium resources.

There is an overriding policy objective that Canada's uranium be used for peaceful non-explosive purposes only. In the case of non-nuclear weapon states, sales are allowed only to those countries that have made a general commitment to non-proliferation by either having ratified the international Treaty on Non-Proliferation of Nuclear Weapons (NPT) or having taken an equivalent binding step, and that have thereby accepted international inspection through the International Atomic Energy Agency (IAEA) of all of their nuclear facilities.

Uranium exports can proceed only to those states (both nuclear and non-nuclear weapon states) which have undertaken to accept, in a formal agreement, a number of additional requirements covering (a) assurance that Canadian-supplied nuclear material, equipment and technology not be used for explosive purposes, (b) retransfer to third parties, (c) the use of highly enriched uranium and plutonium derived from Canadian material, (d) physical protection and (e) standby safeguards. This last provision would come into effect should IAEA safeguards ever cease to apply for any reason.

Elements of export policy are in place that seek to ensure adequate supplies of uranium for domestic needs, to provide fair returns to Canadians from exportable surpluses, and to realize opportunities for further processing.

Following the implementation of the Canada/United States Free Trade Agreement (FTA) on January 1, 1989, the Canadian government initiated an overall review of the commercial aspects of Canada's uranium export policy. This review was prompted by a desire to ensure that the policy would facilitate the industry's search for new business opportunities, while maintaining Canada's nuclear non-proliferation and security objectives, and maintaining consistency with Canada's commitments under the GATT and the FTA. A companion objective was to simplify the administration of the policy, and make it easier for Canada's uranium customers to understand.

The results of the review were outlined in a letter from the Minister of Energy, Mines and Resources to the Canadian uranium industry, dated May 18, 1990. Canada will continue to monitor domestic security of supply, while relaxing contract requirements. Toward this end, the maximum approval period on export contracts has been extended from 15 years to 30 years from the date of contract execution, and the requirement that individual Canadian utilities must demonstrate that they have uranium purchase contracts in place to cover their uranium requirements for a specified period of time has been eliminated. [13]

The Canadian government continues to expect pricing terms in export contracts to provide for an equitable balance of benefits and risks, and to be generally not less favourable than those being obtained in the same time period by competing Canadian and international producers for contracts of similar duration. In the interests of promoting stable productivity and employment, each export contract should include mechanisms, such as escalating floor price provisions, which will help to reduce the impact of unexpected

shifts in the market, and thereby contribute to a more predictable commercial environment for both the company and its employees.

The uranium export contract review process is relatively smooth and efficient, and the related policies are applied in a realistic and pragmatic manner.

With respect to uranium further processing, the Canadian government will require that Canadian uranium destined for use as enriched uranium fuel shall be upgraded to the maximum extent possible in Canada before export, as long as Canada's conversion facilities have the capacity. Exemptions to this requirement will be granted in cases where: i) the uranium will be converted or enriched or consumed in the United States, or ii) the Canadian converter is not the successful bidder for conversion services as a result of purely commercial considerations.

All uranium export contracts are reviewed by federal government authorities to ensure that they meet the intent of these export policy objectives. For contracts that are found to be consistent with these objectives, export licences and export permits are obtained annually from the regulatory authorities.

Finally, Ministers concluded that the uranium export policy should continue to be applied in a pragmatic manner, and that the current review process has proven to be efficient and responsive to the needs of the Canadian producers. It was therefore decided that the examination of uranium export contracts by the interdepartmental Uranium Exports Review Panel will be continued.

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APPENDIX 4

FOREIGN OWNERSHIP IN THE URANIUM MINING SECTOR

In December 1987, Canada's Minister of State for Forestry and Mines announced a new policy on non-resident ownership in the uranium mining sector. The new policy is designed to encourage investment in Canada's uranium mining industry, and to promote economic development, exports and jobs for Canadians. It will provide considerable flexibility to investors, both Canadian and foreign, and should significantly facilitate the efforts of those interested in financing the development of recent Canadian uranium discoveries.

The primary objective of the new policy is a 51 per cent level of Canadian equity in an individual uranium property when production begins. However, lower levels of Canadian ownership would be permitted if Canadian control can be clearly demonstrated. Only in cases where Canadian partners cannot be found would exemptions to the policy be considered, and these would require Cabinet approval. These new criteria are considerably more liberal than those in previous policy. There continues to be no restrictions on foreign participation in Canada's uranium industry at the exploration stage. [13]

APPENDIX 5

ENERGY CONVERSION FACTORS

Requests for factors to convert quantities of uranium into common units of energy for comparison with other energy sources have occurred during recent years with increasing frequency. In response to these needs, the NEA/IAEA developed such factors for various reactor types for inclusion in their 1988 *Red Book*. These factors can be used, together with standard conversion and energy equivalent factors for fossil fuels, to arrive at the thermal energy equivalents of various energy sources. Readers may find that the factors provided on the next page are useful.

APPENDICES

ENERGY CONVERSION FACTORS

1 tU utilized in a CANDU once-through fuel cycle = 0.691×10^{15} Joules

or

1 tU utilized in a typical LWR/PWR once-through fuel cycle = 0.45×10^{15} Joules

•

10^{12} Joules = 1 Terajoule (TJ) = 23.885 Tonnes of Oil Equivalent (TOE)

and

1×10^{6} TOE (MTOE) = 42 Petajoules (10^{15} Joules)

•

1 MTOE = 93 tU (in typical LWR/PWR reactor)

or

1 MTOE = 61 tU (in CANDU reactor)

or

1 MTOE = 84 tU (for energy equivalent of Canadian uranium production)
[assumes 85% exported for LWR/PWR use and 15% for domestic use]

•

1 MTOE = 7.58×10^{6} barrels of oil
1 MTOE = 1.111×10^{9} m^3 natural gas
1 MTOE = 1.5×10^{6} tonnes of hard coal
1 MTOE = 3.0×10^{6} tonnes of soft coal

REFERENCES

Whillans, R.T., URANIUM (a Review of the Canadian Uranium Industry in 1990), Northern Miner Magazine, March 1991.

Williams, R.M., and Whillans, R.T., CANADA'S URANIUM INDUSTRY - PROSPECTS FOR THE FUTURE, a paper presented at the Uranium Seminar hosted by the United States Council for Energy Awareness, St. Petersburg, Florida, September 23, 1991.

Morrison, R.W. and Whillans, R.T., CANADIAN URANIUM AND NUCLEAR INDUSTRY DEVELOPMENTS, a paper presented at the Uranium Seminar hosted by the United States Council for Energy Awareness, San Antonio, Texas, September 17, 1990.

Mackenzie, B.W. et al, URANIUM MINING IN CANADA AND AUSTRALIA: THE IMPACT OF TAXATION, a report prepared jointly by the Centre for Resource Studies of Queen's University at Kingston, Ontario, and the Uranium Division - Electricity Branch of the Department of Energy, Mines and Resources, Ottawa, September 1991.

URANIUM IN CANADA: 1989 ASSESSMENT OF SUPPLY AND REQUIREMENTS, Energy, Mines and Resources Canada, Report EP 89-3, September 1989.

Morrison, R.M. and Brown, P.A., RADIOACTIVE WASTE MANAGEMENT IN CANADA, a paper presented at the Sixteenth Annual Symposium of the Uranium Institute, London, England, September 6, 1991.

NUCLEAR ENERGY DATA, [the "Brown Book"], OECD, Paris, 1991.

Ruzicka, V., CONCEPTUAL GENETIC MODELS FOR IMPORTANT TYPES OF URANIUM DEPOSITS AND AREAS FAVOURABLE FOR THEIR OCCURRENCE IN CANADA, IAEA - TECDOC - 500, pp. 49-79, 1989.

Bell, R.T., A CONCEPTUAL MODEL FOR DEVELOPMENT OF MEGABRECCIAS AND ASSOCIATED MINERAL DEPOSITS IN WERNECKE MOUNTAINS, CANADA, COPPERBELT, ZAIRE, AND FLINDERS RANGE, AUSTRALIA, IAEA - TECDOC - 500, pp. 149-170, 1989.

Cranstone, D.A. and Whillans, R.T., AN ANALYSIS OF URANIUM DISCOVERY COSTS IN CANADA, 1930-1983, Rates of Discovery, Exploration Expenditures, Discovery Costs and Geological Deposit Types, IAEA - TECDOC - 500, pp. 29-48, 1989.

[11] NEA/IAEA, URANIUM - RESOURCES, PRODUCTION AND DEMAND, [the "Red Book"], and subsequent STATISTICAL UPDATE, OECD, Paris, 1990.

[12] *Williams, R.M.*, WORLD URANIUM SUPPLY - WILL THERE BE ENOUGH?, a paper presented to the Finnish Nuclear Society, Helsinki, Finland, March 16, 1989.

[13] *Smith, K.L. and Williams, R.M.*, CANADA'S URANIUM POLICIES, a paper presented at the Fifteenth Annual Symposium of the Uranium Institute, London, England, September 6, 1990.

Note: OECD and IAEA documents are available in Canada through:

Renouf Publishing Company Limited
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